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4

Example CFIT Training Program

4.0 Introduction

The overall goal of this CFIT Education and Training Aid is to reduce CFIT accidents and incidents through appropriate education and training. The Example CFIT Training Program is an example of the type of training that should be conducted to meet that goal. The program is primarily directed toward two aspects of the CFIT problem: avoidance and escape.

The most important goal for any flight crew is maintain vertical and horizontal situational awareness in relation to the ground, water, and obstacles. When this is not accomplished and the potential for impact with the ground, water, or obstacles is imminent, the proper escape maneuver must be used to improve the chance of surviving.

This CFIT training program is structured to stand alone, but it may be integrated into existing initial, transition, and recurrent training and check programs. The Academic Training Program is designed to improve awareness by increasing the flight crew's ability to recognize and avoid impending CFIT situations. The Simulator Training Program is designed to apply this knowledge as well as develop proficiency in an escape maneuver that must be used as a last resort for survival.

The Academic Training Program consists of a description and a suggested method for applying the academic training portions of this CFIT Education and Training Aid. For pilots who do not receive simulator training, it provides a comprehensive review of the factors and causes of CFIT accidents and incidents and ways to avoid CFIT traps. For pilots who undergo simulator training, this program prepares them for the decision making needed and critical performance required to avoid a CFIT accident.

The Simulator Training Program includes a simulator briefing outline and two simulator exercises. These exercises are designed for flight crews to practice the escape maneuver and demonstrate airplane performance in critical situations. The second simulator scenario requires flight crews to recognize CFIT traps and make critical decisions in order to avoid an accident.

The simulator implementation information assists simulator technical personnel in incorporating a potential CFIT scenario into the simulator database and lesson plans. It also provides data that may be used in developing a simulator that accurately reflects airplane performance characteristics.

4.1 Academic Training Program

The Academic Training Program contains several instruction modules. These modules may be used as a stand-alone program or in combination with existing training programs and the Simulator Training Program.

4.1.1 Academic Training Objectives

The objectives of the Academic Training Program are to provide the pilot with the ability to:

- Recognize the factors that may lead to CFIT accidents and incidents.
- Know the prevention strategies that will ensure a safe flight.
- Improve situational awareness in order to avoid CFIT.
- Learn an escape maneuver and techniques designed to enhance the possibility of survival.

A suggested syllabus is provided. All of the individual training materials are designed to stand alone or be used as a part of a larger program. No single training format is best for all training situations. Therefore, a modification should be made to meet specific training requirements. There is some redundancy in subject material in order to provide flexibility. It is recommended that the training materials be used in sequence when used as a stand-alone program.

4.1.2 Academic Training Program Modules

The following academic training modules are available to prepare an academic training program:

- Operators Guide (CFIT Education and Training Aid, Section 3) is a comprehensive study of CFIT, its causes, contributing factors, and solutions to counter the factors and prevent CFIT accidents. This is a source document that may be reviewed at any time by the flight crew and others in the operations spectrum of the aviation industry. Pilots should read this before formal CFIT academic or simulator training.

- The Operators Guide to CFIT Questions (Appendix 4-B) is a set of questions designed to test the flight crew's knowledge of each section of the Operators Guide. In a CFIT training curriculum, these questions may be used as a part of the review of the Operators Guide or as an evaluation to determine the effectiveness of self-study before academic or simulator training.
- The CFIT Safety Briefing (Appendix 4-C) is a paper copy of overhead viewfoils, with the descriptive words for each foil. This briefing may be used as a classroom or one-on-one presentation, and it supports a discussion of the Operators Guide.
- The video "CFIT: An Encounter Avoided" addresses the CFIT problem in its entirety. It shows the causes and contributing factors of CFIT accidents and incidents and emphasizes how to avoid CFIT. The video also presents the CFIT prevention safety philosophy of some leaders in the aviation industry. Finally, the video points out future capabilities of the GPWS. A copy of the video script is provided in Appendix 4-E.

4.1.3 Academic Training Syllabus

Combining all of the academic training modules results in the following suggested Academic Training Syllabus (Figure 1).

4.1.4 Additional Academic Training Resources

Section 5, CFIT Background Material, is an excellent source of information for an instructor who seeks more information or detailed explanations of material contained in the Operators and Decision Makers Guides. The video script "CFIT: An Encounter Avoided" is also an excellent source of information. Throughout the Operators Guide are figures and charts that may be used individually to stress certain teaching points. The Instructor Pilot Syllabus Briefing Supplement, Appendix 4-A, provides detailed information about the GPWS operating modes.

4.2 CFIT Simulator Training Program

The Simulator Training Program provides the opportunity for pilots to practice CFIT prevention strategies, but it primarily addresses the second aspect of avoiding CFIT accidents: the escape maneuver. ***Note: The term "maneuver" is associated with the sequence of steps the pilot is required to accomplish in order to avoid impact with the terrain. It is recognized that some airplane manufacturers have established procedural steps that the pilot is required to accomplish for that particular airplane. For simplicity, the term "maneuver" will be used for both situations.*** Training and practice are provided for the pilot to experience realistic situations that require timely decisions and correct responses. During the training, the escape maneuver should be practiced to proficiency by both pilots. This training can be inserted into existing simulator profiles during less intensive workload periods. Initial training

Figure 1
Academic Training Syllabus

Training Module	Presentation Method
Operators Guide	Self-study/classroom
Operators Guide to CFIT Questions	Self-study/classroom
Video, "CFIT: An Encounter Avoided"	Classroom
CFIT Safety Briefing	Classroom

should occur in VMC and should emphasize the need to react to all GPWS warnings.

To be fully effective, the simulator training requires the student to be knowledgeable of the materials in the academic training portion of this aid.

Effective flight crew coordination should be emphasized, especially when operating in the high-potential-CFIT phases of flight: takeoff, approach, and landing. Each operator should consider incorporating unique airports and conditions from its route structure into its individual CFIT simulator training program. Some suggestions for CFIT scenarios include:

- A low-altitude level-off just after takeoff, with a radar vector turn toward high terrain, and no subsequent vectoring.
- An early enroute descent into a mountainous/hilly terminal area in an intensive communications environment.
- A missed approach with a low-altitude level-off and a turn toward high terrain.

4.2.1 Simulator Training Objectives

The objective of the Simulator Training Program is to provide the flight crew with the ability to:

- Recognize the contributing factors that can lead to a CFIT incident.
- Maintain proper horizontal and vertical situational awareness.
- Communicate and coordinate on the flight deck during critical phases of flight.
- Recognize a potential CFIT situation and take appropriate action to avoid it.
- Gain confidence in the GPWS.
- Perform a successful CFIT escape maneuver.

4.2.2 Simulator Training Syllabus

CFIT simulator training should be given during initial, transition, and recurrent training. This training should follow a building block approach to learning. It is recognized that there are many contributing factors that may lead to the loss of vertical and horizontal situational awareness by the flight crew. Because of this, the flight crew cannot be exposed to all of the situations in the simulator that they may confront during their normal flight operations. However, a well-structured training program will include exposure to a sufficient number of contributing factors in each exercise to make the training as realistic as possible. The simulator training should include:

- A briefing.
- A minimum of two exercises. Refer to Figure 2.
- A critique.

4.2.3 Pilot Simulator Briefing

Before the first CFIT exercise:

- Review contributing factors and causes of CFIT accidents.
- Explain the need for good flight crew coordination throughout the flight, but especially during critical phases, such as takeoff, approach, and landing.
- Discuss the GPWS operating modes.
- Review the airplane escape maneuver/procedure and pilot techniques.
- Discuss common flight crew errors.

Figure 2
Summary of Simulator Training

Exercise	Description	Training Objectives
1	Insert a simulator "mountain*" in VFR conditions during flight on the downwind leg of the traffic pattern.	Demonstrate GPWS warnings and proper response times and procedures for the escape maneuver.
2	Insert a simulator "mountain*" in IMC during an appropriate phase of flight.	Demonstrate flight crew awareness and coordination in CFIT situations. Practice correct escape maneuver procedures.

* Invisible, rapidly rising terrain simulator feature.

Before the second CFIT exercise:
- Review the need for crew awareness and coordination.
- Discuss the importance of knowing GPWS warnings and the requirement for rapid flight crew response to these warnings.
- Review CFIT traps.
- Review the escape maneuver/procedure and pilot techniques.

4.2.3.1 Generic GPWS Warning Escape Maneuver

It is understood that each airplane type is different. Airplanes produced by one manufacturer may have different technologies that could dictate separate maneuvers. Appendix 4-D shows the escape maneuver for the airplanes of several manufacturers. If your airplane is not included in the appendix, contact the manufacturer and request the information. ***If your airplane manufacturer or operations policy or operations manual does not provide a GPWS warning escape maneuver or procedure, use the following maneuver.***

These steps must be taken immediately in response to a GPWS warning, except in clear daylight VMC when the flight crew can immediately and unequivocally confirm that an impact with the ground, water, or an obstacle will not take place:
- React immediately to a GPWS warning.
- Positively apply maximum thrust and rotate to the appropriate pitch attitude for your airplane.
- Pull up with wings level to ensure maximum airplane performance.
- Always respect stick shaker.

Continue the escape maneuver until climbing to the sector emergency safe altitude can be completed or until visual verification can be made that the airplane will clear the terrain or obstacle, even if the GPWS warning stops.

4.2.4 Simulator Exercises

These are detailed descriptions of sample simulator training exercises. They illustrate the type of information that training departments should pass on to the flight crews. To optimize learning, these exercises may be modified by individual training departments to better fit their particular syllabus, operating area, and requirements. The scenarios are designed to introduce CFIT into the overall training environment without requiring that a large amount of time be devoted to the subject. These scenarios will give the student the basic knowledge of CFIT, its causes, and how to escape from a potential CFIT encounter.

4.2.4.1 Exercise 1: VMC Initial Introduction of Potential CFIT

The initial conditions for this exercise should be typical for the airfield and airplane model of the operator. These should represent “average” conditions, so as not to detract from the primary purpose of developing proficiency in the mechanics of the CFIT escape maneuver. The CFIT encounter should be prompted by a clear indication of the problem when the electronic “mountain” appears in front of the airplane. The duration of the escape maneuver should be long enough that the airplane is flown to its maximum performance and continues at maximum performance, so that the pilot demonstrates proficiency at maintaining airplane maximum performance and a safe altitude. This should take several thousand feet of altitude gain. The instructor may then remove the “mountain.”

The airplane weight should be appropriate for the visual pattern, but heavy enough to make the escape maneuver realistic. After the “mountain” appears, the instructor should ensure that the flight crew is aware of the GPWS warnings and fully understands their meanings. The escape maneuver should be accomplished using the appropriate airplane maneuver. Repeat the exercise, as needed, so that the flight crew understands the requirement for rapid response to the warning and it has attained proficiency in maintaining maximum airplane performance and executing the escape maneuver.

Initial conditions:

Airplane: appropriate for the operators fleet.
Airplane gross weight: near maximum landing weight.
Flaps: approach setting for the airplane.
Center of gravity: appropriate for the airplane.
Ceiling and visibility: clear.
Wind: calm.
Temperature: 80°F/24°C.
Airport elevation: appropriate for operators airfields.
Altimeter QNH: 29.92/1013.

Pilot requirements:
Upon receiving a GPWS warning, the pilot will practice the CFIT escape maneuver. ***If your airplane manufacturer or operations policy or operations manual does not provide a GPWS warning escape maneuver or procedure, use the following maneuver:***

- React immediately to a GPWS warning.
- Positively apply maximum thrust and rotate to the appropriate pitch attitude for your airplane.
- Pull up with wings level to ensure maximum airplane performance.
- Always respect stick shaker.

Continue the escape maneuver until climbing to the sector emergency safe altitude or until visual verification can be made that the airplane will clear the terrain or obstacle, even if the GPWS warning stops.

Demonstrate proper flight crew coordination. Monitor the radio altimeter during the maneuver. The pilot not flying should call out the radio altitudes and trend, e.g., “500 feet, decreasing”; “300 feet, decreasing”; “600 feet, increasing.” The maneuver should be continued until the maximum performance of the airplane is reached and a safe altitude is attained.

4.2.4.2 Exercise 2: IMC Potential CFIT Encounter

The airplane should be nearly at maximum allowable weight for takeoff or landing. Ensure that the weights do not exceed the airplane limits. The exercise may include takeoff, followed by a low altitude level-off or a maximum weight landing. Either scenario should be in IMC to ensure that the flight crew does not see the “mountain” as they approach it. With the correct “mountain” in the simulator database, the pilot must perform the escape maneuver properly in order to avoid impact with the terrain. This “mountain” is actually a given angle that will require the pilot to attain the maximum airplane performance. The duration of the escape maneuver should be long enough that the airplane is flown to its maximum performance. It should continue at maximum performance so that the pilot demonstrates proficiency at maintaining airplane maximum performance and a safe altitude. This should take several thousand feet of altitude gain. The instructor may then remove the “mountain.” Repeat this exercise as necessary for the flight crew to become proficient in recognizing CFIT traps and executing the escape maneuver.

Initial conditions:
Airplane: appropriate for the operators fleet.
Flaps: appropriate for the phase of flight.
Center of gravity: appropriate for the airplane.
Ceiling and visibility: 200-ft ceiling/0.5 mi visibility.
Wind: calm.
Temperature: 80°F/24°C.
Airport elevation: appropriate for operators airfields.
Altimeter QNH: 29.92/1013

4.2.5 Pilot Requirements

Particular attention must be paid to situational awareness throughout this lesson. Good flight crew coordination is essential to the success of the exercise. Flight crews should be aware of the controls and indicators associated with the GPWS. Accidents have happened because the system has been deactivated or inhibited. Flight crews should not inhibit the GPWS unless they can immediately and unequivocally confirm that an impact with the ground, water, or an obstacle will not take place. Upon receiving a GPWS warning, the pilot will execute the CFIT escape maneuver. In the absence of an airplane manufacturer’s established maneuver, use the following maneuver:

- React immediately to a GPWS warning.
- Positively apply maximum thrust and rotate to the appropriate pitch attitude for your airplane.
- Pull up with wings level to ensure maximum airplane performance.
- Always respect stick shaker.

Continue the escape maneuver until climbing to the sector emergency safe altitude or until visual verification can be made that the airplane will clear the terrain or obstacle, even if the GPWS warning stops.

Demonstrate proper flight crew coordination. Monitor the radio altimeter during the maneuver. The pilot not flying should call out the radio altitudes and trend, e.g., “500 feet, decreasing”; “300 feet, decreasing”; “600 feet, increasing.” The maneuver should be continued until the maximum performance of the airplane is reached and a safe altitude is attained.

4.3 Simulator Implementation

This is designed to assist the simulator programming and checkout departments. If not previously accomplished, the addition of a pop-up “mountain” will be required in the simulator models. Ideally, the “mountain” feature should include an adjustable slope of up to a minimum of 17 deg, and it should be controllable by the simulator instructor. As a minimum, the “mountain” must be capable of triggering the GPWS warning, and it must meet the requirements of the exercises described in Sections 4.2.4.1 and 4.2.4.2. The biggest challenge, once this “mountain” is installed, is to ensure that the simulator accurately reflects the handling characteristics of the particular airplane. This is especially true at very heavy airplane weights.

4.3.1 Simulator Fidelity Check

Operators that use this training aid should ensure that the simulator scenarios accurately reflect airplane characteristics and performance to the extent necessary to achieve the training objectives. In order to prevent negative learning experiences, it is important that unrealistic simulator characteristics be removed and the proper simulation of the “mountain” be provided.

Certified full-flight simulators generally contain testing programs that enable engineers to confirm the accuracy of the simulation. When purchasing new simulators, ensure that the data from the manufacturer are up to date in order to accurately simulate maximum performance climbs necessary for the CFIT escape maneuver. The concept is to meet the training objectives by taking full advantage of simulator quality. In older simulators, always strive to improve simulator fidelity.

The simulator manufacturer should be consulted, if necessary, in order to provide the capability to support this CFIT prevention training.

4.3.2 Computer Analysis/Simulator Study Data Requirements

The analyses are shown in Appendix 4-D. These analyses and simulator studies are divided into different subsections for each manufacturer. Whenever possible, the data shown are for identical parameters. When different parameters are used, they will be noted in the analysis. Each scenario will be studied for time versus distance and time versus altitude gained. For commonality, the data were derived using the following parameters:

- Weight: maximum takeoff.
  Flaps: takeoff position.
  Landing gear: up.
  Speed: V2.
  Thrust: maximum applied at GPWS warning.

- Weight: maximum landing.
  Flaps: up.
  Landing gear: up.
  Speed: maneuvering.
  Thrust: maximum applied at GPWS warning.

- Weight: maximum landing.
  Flaps: approach position.
  Landing gear: down.
  Speed: minimum flap speed.
  Thrust: maximum applied at GPWS warning.

- Weight: maximum landing.
  Flaps: landing position.
  Landing gear: down.
  Speed: VRef plus 5 kt.
  Thrust: maximum applied at GPWS warning.

Time versus distance and time versus altitude gained plots will be taken for each pull-up. These plots will also be recorded to the stick shaker using the following parameters:

- 3-deg/s pull-up to 15 deg and continue to stick shaker.
- 3-deg/s pull-up to 20 deg and continue to stick shaker.
- 4-deg/s pull-up to 15 deg and continue to stick shaker.
- 4-deg/s pull-up to 20 deg and continue to stick shaker.

Instructor Pilot Syllabus Briefing Supplement

A potential CFIT situation is clearly an unanticipated event on the part of the flight crew. The warnings come unexpectedly, and they often require the flight crew to make decisions based on only one stimulus, instead of the many confirming stimuli associated with routine flight events. Since the Captain is responsible for the safety of the passengers, flight crew, and airplane, he or she should exercise appropriate emergency authority to respond to the situation.

If airplane-unique GPWS information is not available, the following information may be used during the simulator briefings. Emphasis should be placed on the capability and credibility of the GPWS. The GPWS is an important piece of safety equipment, and recent versions can be programmed to accommodate an operator's particular needs.

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4-A.1 GPWS Warning Modes (Mark VI)

GPWS Mode 1

Mode 1 provides alerts and warnings for excessive rates of descent with respect to the airplane's possible collision with the ground. Radio Altitude and Barometric Decent Rate (FMP) are monitored to determine Mode 1 warning conditions (Figure 1A).

Two distinct audio warnings, "Sinkrate" and "Pull up" are generated by Mode 1. During these alerts the red "GPWS Warn" lamp is illuminated. When the outer warning curve is penetrated, the "Sinkrate" alert is repeated every 3 sec. If the airplane descent continues into the inner warning curve, the emphatic "Pull up!" alert is given. Both alerts stop when the airplane exits the warning curve.

Mode 1 is automatically desensitized when repositioning the airplane down onto a glide slope beam (Figure 1B). This allows pilots more room to maneuver the airplane without triggering an alert.

When the airplane is below a glide slope centerline, the Mode 1 sensitivity is increased. This provides additional warning time for excessive descents when below the glide slope.

Figure 1A
Mark VI GPWS
Mode 1

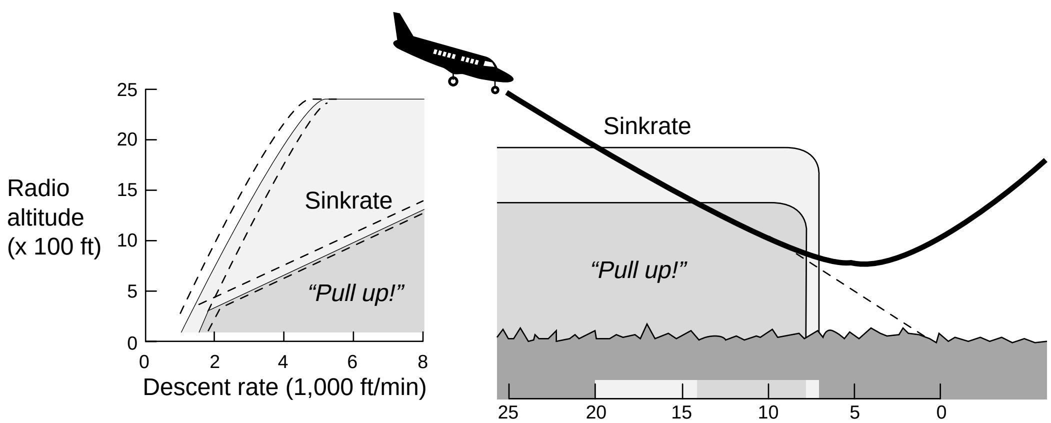
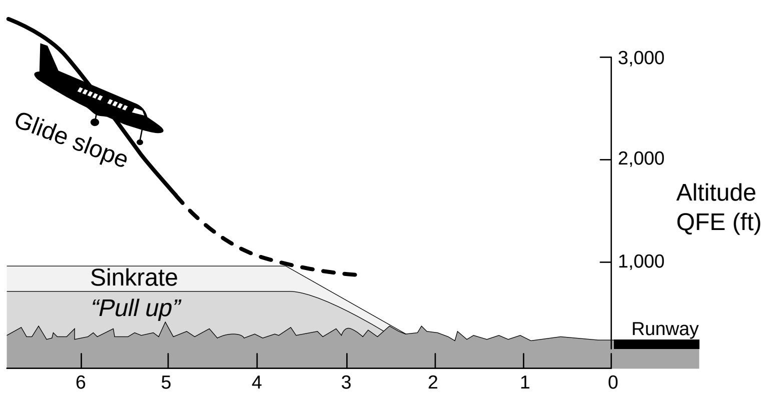


Figure 1B
Mark VI GPWS
Mode 1



GPWS Mode 2

Mode 2 supplies warning protection when terrain below the airplane is rising dangerously fast. These warnings are given well ahead of the airplane's projected collision with terrain. Radio Altitude (AGL) and Terrain Closure Rate is monitored to determine Mode 2 alerts (Figure 2A). Mode 2 also expands as a function of airplane speed. The faster the airplane is traveling, the sooner the excessive closure rate alerts are given.

"Terrain, Terrain!" and "Pull Up!" audio warnings are produced by Mode 2. During Mode 2 alerts, the red "GPWS Warn" lamp is illuminated. When the outer Mode 2 curve is penetrated, the "Terrain, Terrain!" call is given once, and it is followed immediately by the "Pull Up!" warning message until the closure rate is no longer present and the curve is exited. The visual "GPWS Warn" lamp will remain illuminated until safe terrain clearance has been restored (Figure 2A).

Manual activation of the "GPWS Flap Override" switch by the pilot will change the Mode 2 curve, as is automatically done when landing configuration is detected by the GPWS. In either case, Mode 2 warnings are desensitized to allow the airplane maneuverability in closer proximity to terrain, when approaching airports, while still providing appropriate terrain warning protection (Figure 2B).

The ability to effect the Mode 2 change with the use of the "GPWS Flap Override" is especially valuable to airplane maneuvering to land in visual conditions at airports in mountainous areas.

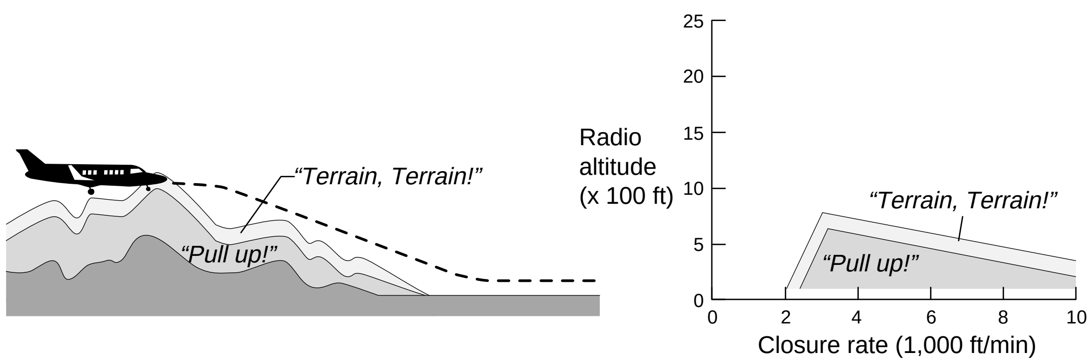


Figure 2A
Mark VI GPWS Mode 2

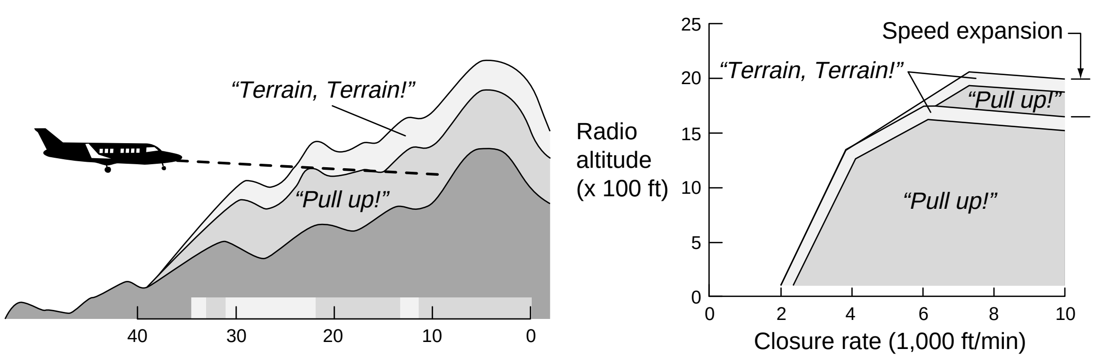


Figure 2B
Mark VI GPWS Mode 2 Desensitized for Landing Configuration

GPWS Mode 3

Mode 3 warns the flight crew of an excessive altitude loss after takeoff or after a missed approach (Figure 3B). Mode 3 monitors the amount of Radio Altitude gained. If Barometric Altitude loss equals approximately 10% of Radio Altitude gained, the “Don’t Sink” audio message is given and the “GPWS Warn” lamp is illuminated (Figure 3A). The “Don’t Sink” warning will stop and the “GPWS Warn” lamp will extinguish when a positive rate of climb is reestablished.

A “Takeoff” or “Missed Approach” is detected when the GPWS computer sees an increase in Airspeed, Radio and Barometric Altitude, gear retraction, etc. Once the airplane reaches 50 ft AGL, Mode 3 is active. Once above 925 feet AGL for 15 to 20 sec, Mode 3 becomes inactive until the GPWS again detects a “Takeoff” or “Go Around.” When Mode 3 becomes inactive, it is replaced by a warning floor below the airplane based on airplane speed and configuration (Figure 4C). This floor protects the airplane for the remainder of the climbout to enroute altitudes.

During training or special pattern work, the “GPWS Flap Override” switch may be activated above 50 ft. This will desensitize the Mode 3 alert envelope to the right, thereby allowing approximately 20% loss of Barometric Altitude before the alert is given (Figure 3A).

Figure 3A
Mark VI GPWS
Mode 3

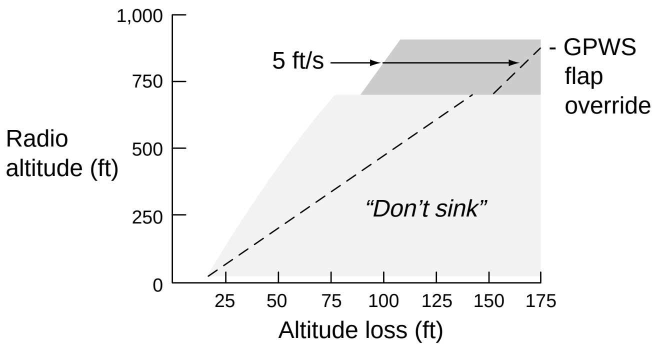


Figure 3B
Mark VI GPWS
Mode 3

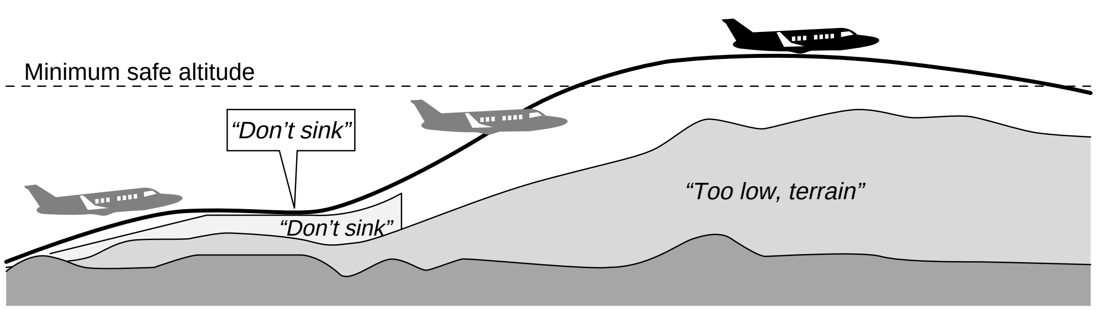
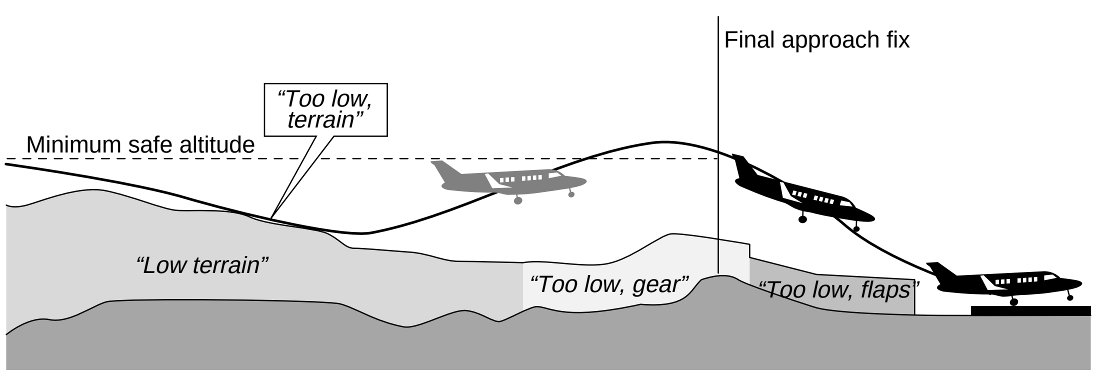


Figure 4
Mark VI GPWS
Mode 4



GPWS Mode 4

Mode 4 warns the flight crew of insufficient terrain clearance during the climbout, cruise, descent, and approach phases of flight. This protection is especially valuable when the airplane's flight path is too shallow to develop excessive closure rates with terrain (Mode 2) or excessive descent rates (Mode 1). Mode 4 has three different alerts, depending on the phase of flight and configuration of the airplane (Figure 3B).

For climbout, cruise, and initial descent during normal flight, the airplane is generally in a clean configuration with gear and flaps up. During these flight phases, the Mark VI provides a "floor" below the airplane to warn of insufficient terrain clearance. At speeds above 200 kt, a "Too Low, Terrain" alert will be given and the red "GPWS Warn" lamp will illuminate if the airplane flies within 750 ft of terrain. At speed from 178 to 200 kt, this same alert will occur, but at lower altitudes AGL corresponding to the slower speed (Figure 4A).

For the initial approach, at speed below 178 kt, the Mark VI monitors airplane configuration. If the airplane descends below 500 ft AGL with landing gear up, the alert "Too Low, Gear" will be given and the red GPWS Warn lamp will illuminate.

On final approach, if the airplane descends below 170 ft AGL with the flaps not in landing configuration, the alert "Too Low, Flaps" will be given and the red "GPWS Warn" lamp will illuminate. This alert may be precluded for landings with partial flaps by pilot activation of the guarded "GPWS Flap Override" switch (Figure 4B).

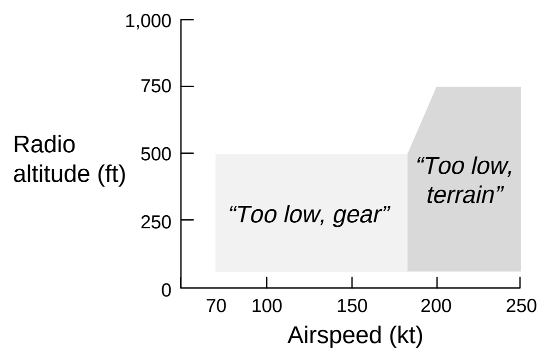


Figure 4A
Mark VI GPWS
Mode 4

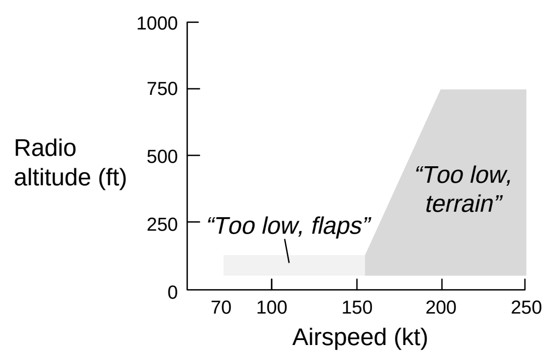


Figure 4B
Mark VI GPWS
Mode 4
Flap Override

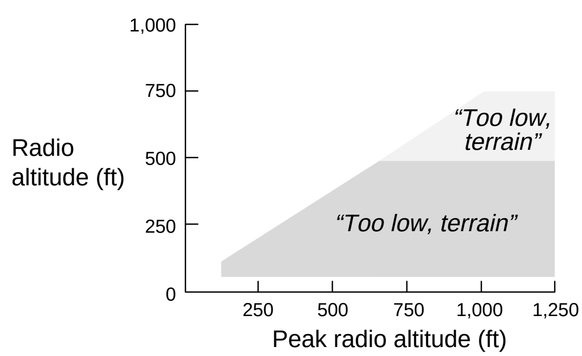


Figure 4C
Mark VI GPWS
Mode 4
Warning Floor

GPWS Mode 5

Mode 5 warns pilots that the airplane is descending below an ILS glide slope. It is automatically armed when the pilot selects an ILS frequency, gear is down, and the airplane is below 925 ft AGL.

The warning envelope contains two boundaries, "Soft" and "Hard," determined by glide slope deviation (Figure 5). When the airplane penetrates the "Soft" alerting region, the audio "Glide slope" warning is given and the yellow "Below Glide slope" lamp illuminates. The initial "Glide slope" message is 6 dB quieter than the system's other audio messages. The audio repetition rate increases as AGL altitude decreases (Figure 5A). If the airplane subsequently enters the "Hard" alerting region, the audio level increases to that of the other audio messages.

Below 150 ft of Radio Altitude, the amount of glide slope deviation required to produce an audio warning is increased to reduce nuisance warnings that could be caused by close proximity to the glide slope transmitter. Mode 5 can be inhibited by pressing the "Below Glide slope" lamp to permit deliberate descent below the glide slope in order to use the full runway under certain landing conditions.

All other warnings, except the excessive bank angle advisory, always have priority over a "Glide slope" alert. With the Mark VI GPWS computer, possible nuisances from erratic glide slope signals are automatically eliminated.

Figure 5
GPWS Mode 5

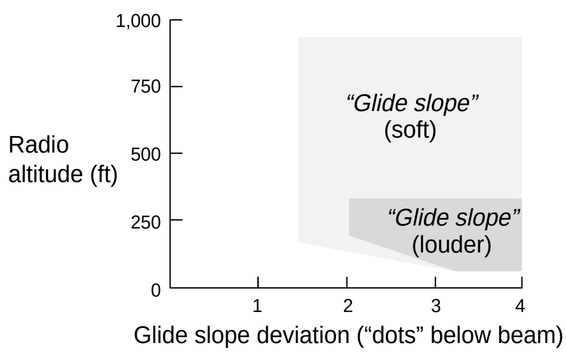
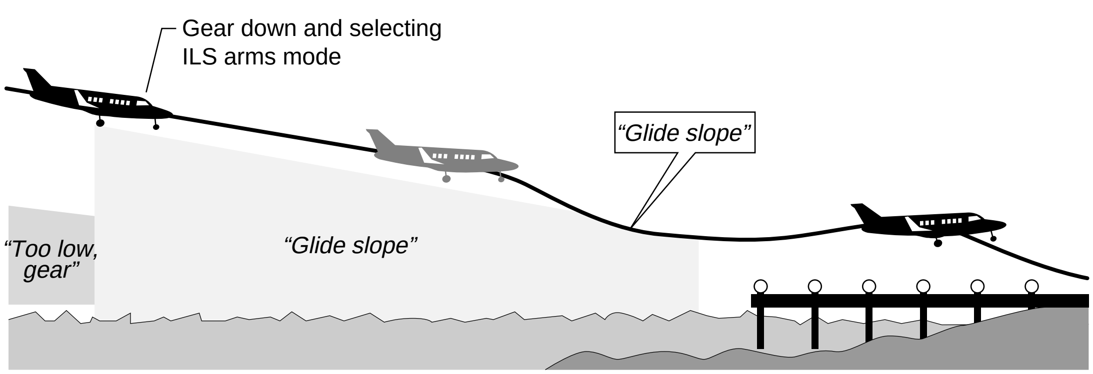


Figure 5A
GPWS Mode 5
Warning Emphasis



GPWS Mode 6

Mode 6 alerts increase situational awareness on final approach and for excessively steep bank angles.

Two audio messages are available to increase altitude awareness on final approach: “Five Hundred” and “Two Hundred” (Figure 7). The “Smart” 500 ft callout occurs once per approach whenever a precision glide slope is not being flown, or if the airplane is well below a glide slope being flown. The 200-ft callout occurs once per approach at 200 ft AGL. The 200-ft callout is always annunciated for altitude awareness.

When the decision height discrete from the radio altimeter indicator is connected to the GPWS, “Minimums, Minimums” is annunciated once per approach as the airplane descends through the “bug” or “DH” setting.

An aural “Bank Angle” warning alerts the flight crew of steep bank angles (Figure 8). The warning limit tightens from 50 deg at 190 ft AGL to 15 deg at ground level (Figure 8). This mode protects flight crews who might be unaware of a potentially dangerous bank angle while maneuvering close to the runway in marginal visibility or at night.

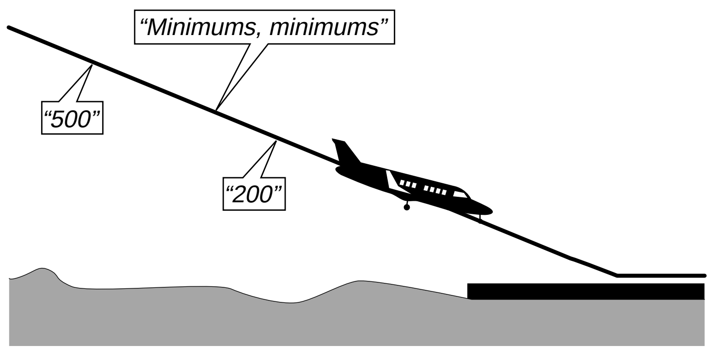


Figure 7
GPWS Mode 6
Smart Callouts

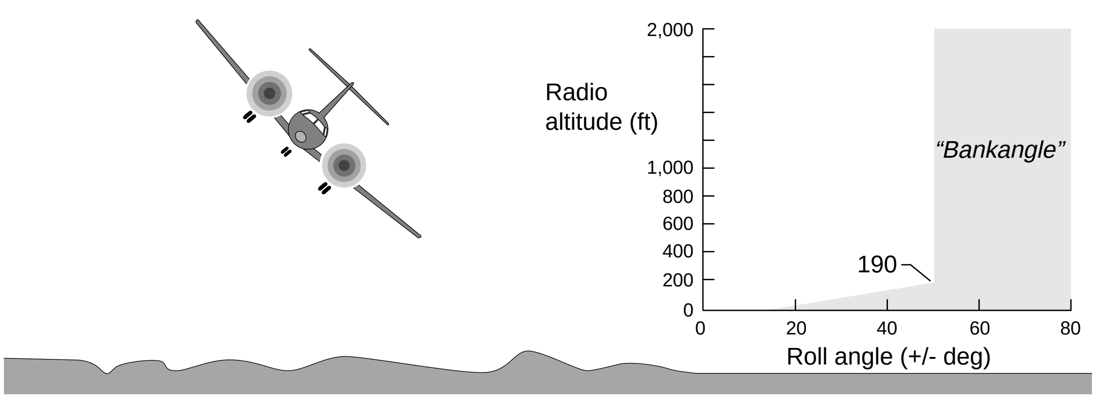


Figure 8
GPWS Mode 6
Steep Bank Angle Callout

Operators Guide to CFIT Questions

This appendix to the Example CFIT Training Program contains an examination covering important areas in Section 3.

The first part of Appendix 4-B contains the Student Examination. Instructions for answering the questions are provided.

The second part of this appendix is the Instructors Examination Guide. This part contains the questions in the Student Examination, the correct answers to each question, and the section in the Operators Guide where the correct answer may be found.

Table of Contents

Student Examination

Instructions

These questions are based on the material in the Operators Guide to the CFIT Education and Training Aid. The questions are all multiple choice, fill in the blank, or true/false questions. There is one answer to each question which is most correct. Circle the correct answer.

Questions

1. The definition of a CFIT accident is an event in which:
   a. An airplane impacts the ground, water, or an obstacle during the descent, approach, or arrival phase of flight.
   b. A mechanically normally functioning airplane is inadvertently flown into the ground, water, or an obstacle.
   c. An airplane is inadvertently flown into the ground, water, or an obstacle because of malfunctioning navigational aids.
   d. An airplane is inadvertently flown into the ground, water, or an obstacle during an inflight emergency.

2. The basic causes of CFIT accidents are:
   a. An insufficient number of instrument approach aids and runway visual aids.
   b. Flight crew complacency and visual illusions.
   c. Altimeter anomalies and complex instrument procedures.
   d. The lack of flight crew vertical and horizontal situational awareness.

3. There are __________ factors that lead to CFIT accidents.
   a. Only a few.
   b. Two.
   c. Only pilot.
   d. Many.

4. Is there an international standard for the altimeter setting unit of measurement?
   a. Yes, and it is inches of mercury.
   b. Yes, but it is not adhered to by all states.
   c. Yes, but it is only adhered to by the United States.
   d. No.

5. If you set an inches of mercury altimeter setting of 29.92 instead of a hectoPascal setting of 992, the airplane will be flying at an altitude that is in error of about:
   a. Plus 600 ft.
   b. Plus 1,000 ft.
   c. Minus 600 ft.
   d. Minus 1,000 ft.

6. If you incorrectly use a QNH altimeter setting instead of a QNE altimeter setting, the airplane's altitude above the ground will be:
   a. Higher than required.
   b. Lower than required.
   c. Higher or lower, depending on the QNH setting.
   d. Insignificant.

7. When pilots accept an ATC enroute clearance to proceed off airway direct to a point:
   a. The clearance ensures safe terrain clearance.
   b. ATC must also include an altitude that ensures safe terrain clearance.
   c. The pilot is responsible for determining a safe altitude and flying at or above it.
   d. None of the above.

8. The best way(s) for flight crews to overcome communication errors with ATC that contribute to CFIT is to:
   a. Exercise good radio communication discipline.
   b. Know the height of the highest terrain or obstacle in the operating area.
   c. Know their position in relation to the surrounding high terrain.
   d. Challenge or refuse ATC instructions when they are not clearly understood, are questionable, or conflict with their assessment of airplane position relative to the terrain.
   e. All of the above.

9. A good way(s) for flight crews to overcome complacency is to:
   a. Know that familiarity can lead to complacency.
   b. Not assume that this flight will be like the last flight.
   c. Adhere to procedures.
   d. None of the above.
   e. All of the above.

10. Many studies show that airlines with established, well thought out and implemented standard operating procedures consistently have safer operations.
    a. True.
    b. False.

11. The majority of CFIT accidents occur during which phase(s) of flight?
    a. Departure.
    b. Enroute and descent.
    c. Landing.
    d. Descent, approach, and landing.

12. In the approach phase of flight, most CFIT accidents occur during:
    a. Visual approaches.
    b. ILS approaches.
    c. ADF approaches.
    d. VOR and VOR/DME approaches.

13. Which of the following recommendations will mitigate the hazards associated with flying a nonprecision instrument approach?
    a. Study the anticipated approach procedure(s) before departure.
    b. Identify unique gradient and step-down requirements.
    c. Review approach procedures during the approach briefing.
    d. All of the above.

14. The autoflight system will sometimes do things that the flight crew did not intend for it to do.
    a. True.
    b. False.

15. When using an autoflight system, flight crews should:
    a. Monitor the system for desired operation.
    b. Avoid complacency.
    c. Follow procedures.
    d. Cross-check raw navigation information.
    e. None of the above.
    f. All of the above.

16. One of the best ways to let the nonflying pilot know what to expect is to conduct a briefing before each takeoff and each approach.
    a. True.
    b. False.

17. To assist in preventing CFIT, the proper use of autoflight systems is encouraged during all approaches and missed approaches, in IMC, when suitable equipment is installed.
    a. True.
    b. False.

18. Route and destination familiarization training programs for flight crews will assist in preventing CFIT accidents and incidents. Written guidance, dispatch briefing material, and video familiarization using actual or simulated representations of destination and alternates is adequate for this training.
    a. True.
    b. False.

19. Flight crews should confirm altimeter setting units by repeating all digits and altimeter units in:
    a. ATC clearance readbacks and intracockpit communications.
    b. Only ATC clearance readbacks
    c. Only initial contact with approach control.
    d. None of the above.

20. It is essential that flight crews always appreciate the altitude of their airplane relative to terrain and obstacles and the assigned or desired flight path.
    a. Always true.
    b. Only during instrument approaches.
    c. Only during darkness or reduced visibility.
    d. Only if the airplane is not equipped with a GPWS.

21. In lieu of any guidance from your standard operating procedures, a callout (aural announcements by either crew member or airplane equipment of significant information that could affect flight safety) should be made:
    a. Upon initial indication of radio altimeter height.
    b. When the airplane is approaching from above or below the assigned altitude.
    c. When the airplane is approaching relevant approach procedure altitude restrictions and minimums.
    d. When the airplane is passing transition altitude/level.
    e. All of the above.
    f. Only c above.

22. Which is the most appropriate flight crew response to a GPWS warning during IMC?
    a. Quickly verify that the warning is valid and execute the escape maneuver, if the warning is valid.
    b. Recheck the barometric altimeter setting and execute the escape maneuver, if the setting is in error.
    c. Immediately execute the escape maneuver.
    d. None of the above.

23. The GPWS escape maneuver should be continued:
    a. Only until the GPWS warning ceases.
    b. Until the airplane has reached the sector emergency safe altitude.
    c. Until visual verification can be made that the airplane will clear the terrain or obstacle.
    d. Answers b or c above.

24. Flight crews should be provided with and be trained to use adequate navigation and approach charts that accurately depict hazardous terrain and obstacles.
    a. True.
    b. False.

25. CFIT accidents and incidents happen insidiously; flight crews fall into traps.
    a. True.
    b. False.

Instructors Examination Guide

Instructions

This guide contains questions that are based on the material in the CFIT Education and Training Aid. The answers to each question can be found in Section 3, Operators Guide of that document. The questions are all multiple choice, fill in the blank, or true/false questions.

There is one answer to each question that is most correct. The correct answer is listed after each question, along with the section where the correct answer may be found.

Questions

1. The definition of a CFIT accident is an event in which:
   a. An airplane impacts the ground, water, or an obstacle during the descent, approach, or arrival phase of flight.
   b. A mechanically normally functioning airplane is inadvertently flown into the ground, water, or an obstacle.
   c. An airplane is inadvertently flown into the ground, water, or an obstacle because of malfunctioning navigational aids.
   d. An airplane is inadvertently flown into the ground, water, or an obstacle during an inflight emergency.

   Answer: b. (Section 3.1)

2. The basic causes of CFIT accidents are:
   a. An insufficient number of instrument approach aids and runway visual aids.
   b. Flight crew complacency and visual illusions.
   c. Altimeter anomalies and complex instrument procedures.
   d. The lack of flight crew vertical and horizontal situational awareness.

   Answer: d. (Section 3.2.1)

3. There are _________ factors that lead to CFIT accidents.
   a. Only a few.
   b. Two.
   c. Only pilot.
   d. Many.

   Answer: d. (Section 3.2.2)

4. Is there an international standard for the altimeter setting unit of measurement?
   a. Yes, and it is inches of mercury.
   b. Yes, but it is not adhered to by all states.
   c. Yes, but it is only adhered to by the United States.
   d. No.

   Answer: b. (Section 3.2.2.1)

5. If you set an inches of mercury altimeter setting of 29.92 instead of a hectoPascal setting of 992, the airplane will be flying at an altitude that is in error of about:
   a. Plus 600 ft.
   b. Plus 1,000 ft.
   c. Minus 600 ft.
   d. Minus 1,000 ft.

   Answer: c. (Section 3.2.2.1)

6. If you incorrectly use a QNH altimeter setting instead of a QNE altimeter setting, the airplane's altitude above the ground will be:
   a. Higher than required.
   b. Lower than required.
   c. Higher or lower, depending on the QNH setting.
   d. Insignificant.

   Answer: c. (Section 3.2.2.2)

7. When pilots accept an ATC enroute clearance to proceed off airway direct to a point:
   a. The clearance ensures safe terrain clearance.
   b. ATC must also include an altitude that ensures safe terrain clearance.
   c. The pilot is responsible for determining a safe altitude and flying at or above it.
   d. None of the above.

   Answer: c. (Section 3.2.2.4)

8. The best way(s) for flight crews to overcome communication errors with ATC that contribute to CFIT is to:
   a. Exercise good radio communication discipline.
   b. Know the height of the highest terrain or obstacle in the operating area.
   c. Know your position in relation to the surrounding high terrain.
   d. Challenge or refuse ATC instructions when they are not clearly understood, are questionable, or conflict with their assessment of airplane position relative to the terrain.
   e. All of the above.

   Answer: e. (Section 3.2.2.4)

9. A good way(s) for flight crews to overcome complacency is to:
   a. Know that familiarity can lead to complacency.
   b. Not assume that this flight will be like the last flight.
   c. Adhere to procedures.
   d. None of the above.
   e. All of the above.

   Answer: e. (Section 3.2.2.5)

10. Many studies show that airlines with established, well thought out and implemented standard operating procedures consistently have safer operations.
    a. True.
    b. False.

    Answer: a. (Section 3.2.2.6)

11. The majority of CFIT accidents occur during which phase(s) of flight?
    a. Departure.
    b. Enroute and descent.
    c. Landing.
    d. Descent, approach, and landing.

    Answer: d. (Section 3.2.2.7)

12. In the approach phase of flight, most CFIT accidents occur during:
    a. Visual approaches.
    b. ILS approaches.
    c. ADF approaches.
    d. VOR and VOR/DME approaches.

    Answer: d. (Section 3.2.2.7)

13. Which of the following recommendations will mitigate the hazards associated with flying a nonprecision instrument approach?
    a. Study the anticipated approach procedure(s) before departure.
    b. Identify unique gradient and step-down requirements.
    c. Review approach procedures during the approach briefing.
    d. All of the above.

    Answer: d. (Section 3.2.2.7)

14. The autoflight system will sometimes do things that the flight crew did not intend for it to do.
    a. True.
    b. False.

    Answer: a. (Section 3.2.2.8)

15. When using an autoflight system, flight crews should:
    a. Monitor the system for desired operation.
    b. Avoid complacency.
    c. Follow procedures.
    d. Cross-check raw navigation information.
    e. None of the above.
    f. All of the above.

    Answer: f. (Section 3.2.2.7)

16. One of the best ways to let the nonflying pilot know what to expect is to conduct a briefing before each takeoff and each approach.
    a. True.
    b. False.

    Answer: a. (Section 3.3.2)

17. To assist in preventing CFIT, the proper use of autoflight systems is encouraged during all approaches and missed approaches, in IMC, when suitable equipment is installed.
    a. True.
    b. False.

    Answer: a. (Section 3.3.3)

18. Route and destination familiarization training programs for flight crews will assist in preventing CFIT accidents and incidents. Written guidance, dispatch briefing material, and video familiarization using actual or simulated representations of destination and alternates is adequate for this training.
    a. True.
    b. False.

    Answer: a. (Section 3.3.4)

19. Flight crews should confirm altimeter setting units by repeating all digits and altimeter units in:
    a. ATC clearance readbacks and intracockpit communications.
    b. Only ATC clearance readbacks.
    c. Only initial contact with approach control.
    d. None of the above.

    Answer: a. (Section 3.3.5)

20. It is essential that flight crews always appreciate the altitude of their airplane relative to terrain and obstacles and the assigned or desired flight path.
    a. Always true.
    b. Only during instrument approaches.
    c. Only during darkness or reduced visibility.
    d. Only if the airplane is not equipped with a GPWS.

    Answer: a. (Section 3.3.5)

21. In lieu of any guidance from your standard operating procedures, a callout (aural announcements by either crew member or airplane equipment of significant information that could affect flight safety) should be made:
    a. Upon initial indication of radio altimeter height.
    b. When the airplane is approaching from above or below the assigned altitude.
    c. When the airplane is approaching relevant approach procedure altitude restrictions and minimums.
    d. When the airplane is passing transition altitude/level.
    e. All of the above.
    f. Only c above.

    Answer: e. (Section 3.3.6)

22. Which is the most appropriate flight crew response to a GPWS warning during IMC?
    a. Quickly verify that the warning is valid and execute the escape maneuver, if the warning is valid.
    b. Recheck the barometric altimeter setting and execute the escape maneuver, if the setting is in error.
    c. Immediately execute the escape maneuver.
    d. None of the above.

    Answer: c. (Section 3.3.7)

23. The GPWS escape maneuver should be continued:
    a. Only until the GPWS warning ceases.
    b. Until the airplane has reached the sector emergency safe altitude.
    c. Until visual verification can be made that the airplane will clear the terrain, or obstacle.
    d. Answers b or c above.

    Answer: d. (Section 3.3.7)

24. Flight crews should be provided with and be trained to use adequate navigation and approach charts that accurately depict hazardous terrain and obstacles.
    a. True.
    b. False.

    Answer: a. (Section 3.3.8)

25. CFIT accidents and incidents happen insidiously; flight crews fall into traps.
    a. True.
    b. False.

Answer: a. (Section 3.4)

Summary of Answers

1. b
2. d
3. d
4. b
5. c
6. c
7. c
8. e
9. e
10. a
11. d
12. d
13. d
14. a
15. f
16. a
17. a
18. a
19. a
20. a
21. e
22. c
23. d
24. a
25. a

CFIT Safety Briefing

CFIT: How Do We Terrain-Proof Our Pilots?

Controlled Flight Into Terrain (CFIT) is defined as an event in which a mechanically normally functioning airplane is inadvertently flown into the ground, water, or an obstacle. Since the beginning of commercial jet operations, more than 9,000 people have died worldwide because of CFIT.

The Flight Safety Foundation organized a CFIT Task Force to study the causes and make recommendations to reduce CFIT accidents by 50% by the year 1998. The Task Force was composed of representatives from aircraft manufacturers, airline operators, government regulators, industry associations, pilots groups, and others.

A consensus was achieved within the industry Task Force, and those recommendations and solutions are included in this briefing.

CFIT:
How Do We Terrain-Proof Our Pilots?

Figure 4-C.1

Hull-Loss Accidents for Worldwide Commercial Jet Fleet

The worldwide accident rate (which includes CFIT) for the commercial jet fleet decreased significantly in the 1960s and in the 1970s. The rate stabilized and remains fairly stable today.

Hull-Loss Accidents for Worldwide Commercial Jet Fleet

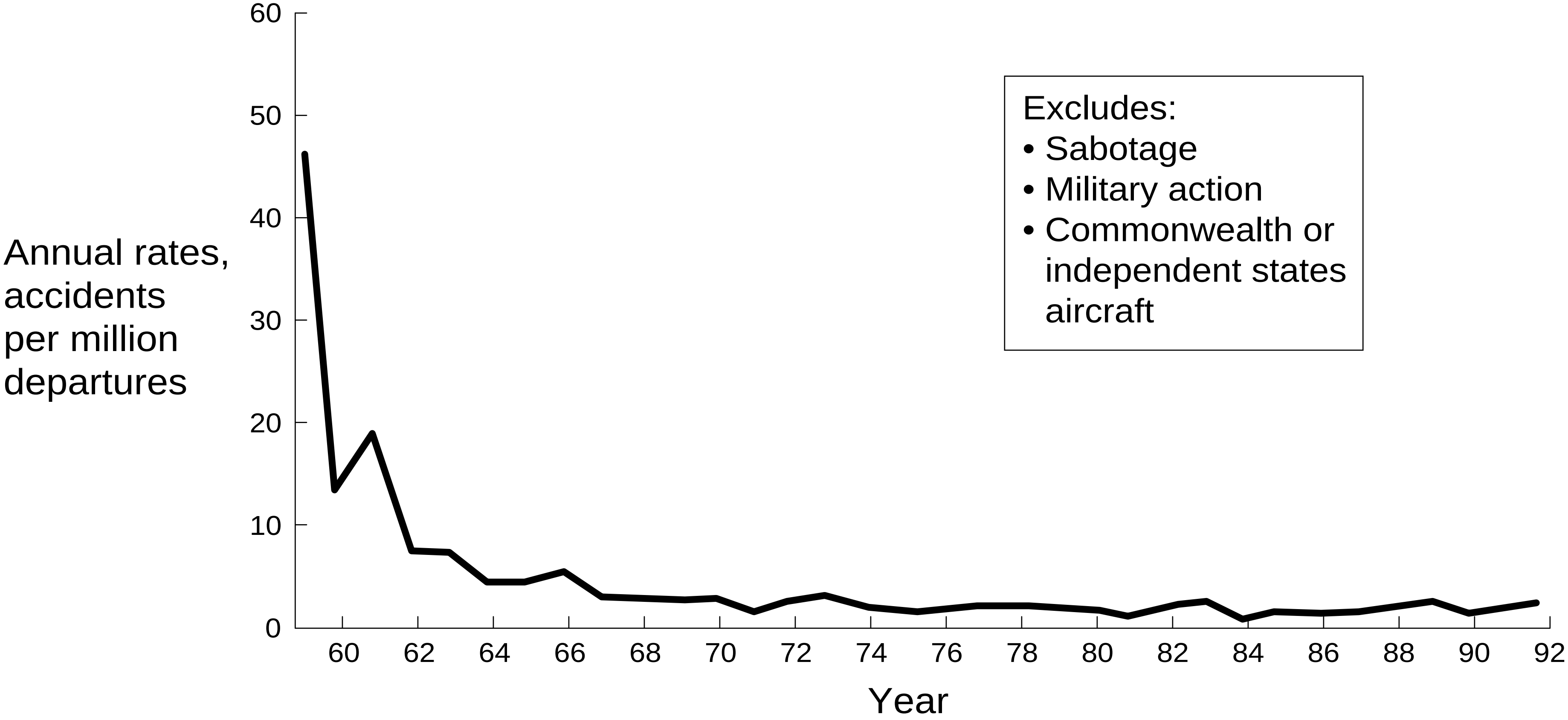


Figure 4-C.2

Controlled Flight Into Terrain

We can be very satisfied with this accomplishment, but let's look at the actual number of CFIT accidents that are included in this accident rate.

Controlled Flight Into Terrain

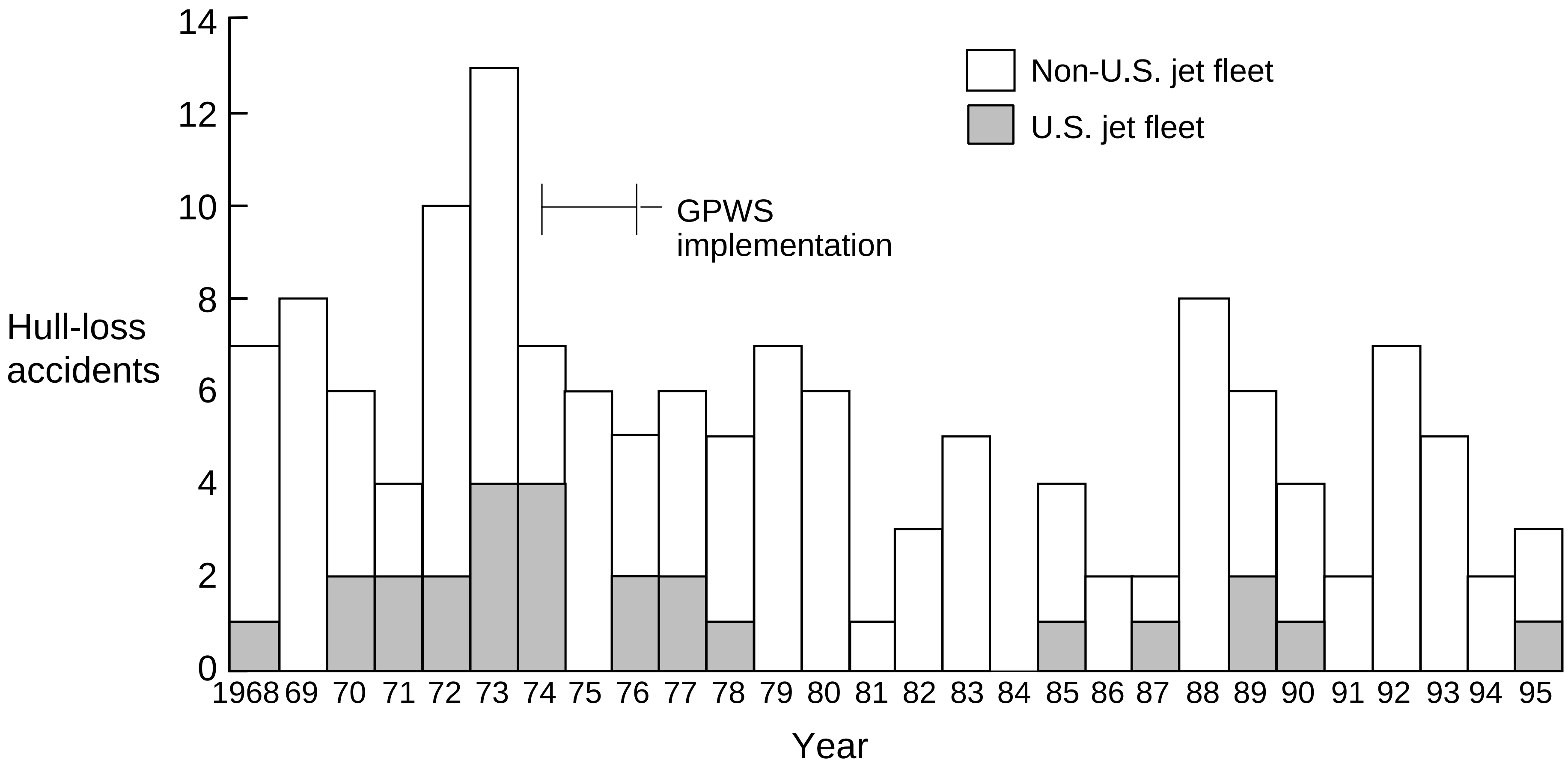


Figure 4-C.3

CFIT Accidents Per Year
USA and World Carriers

This chart shows hull losses attributed to CFIT for the United States fleet as well as the rest of the world’s fleet. The reduction in CFIT accidents that started in 1975 will be discussed later. The important thing to understand about these accidents is that they happened with normally functioning airplanes.

These are accidents that operators could have prevented!

CFIT Accidents Per Year

USA and World Carriers

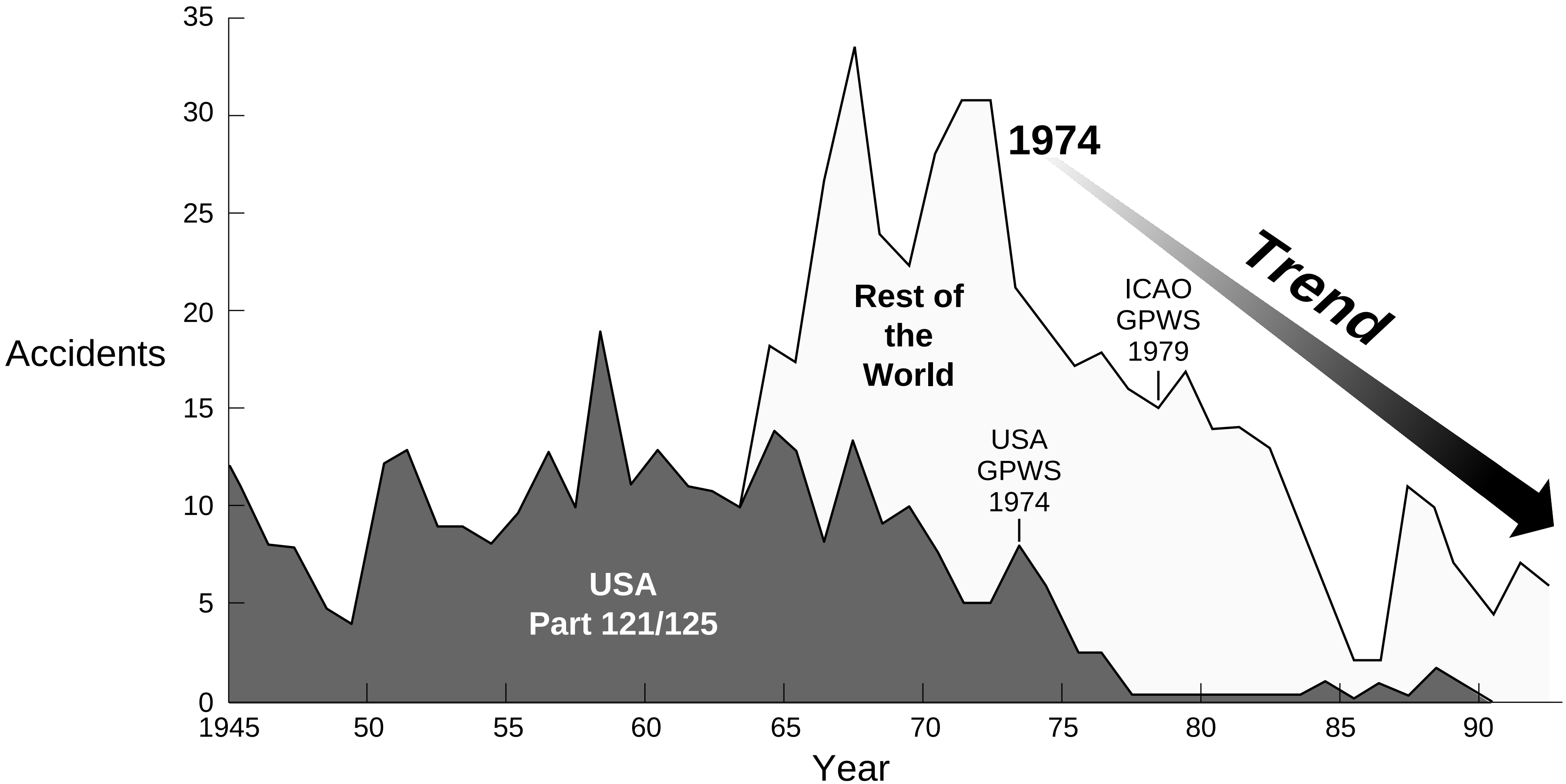
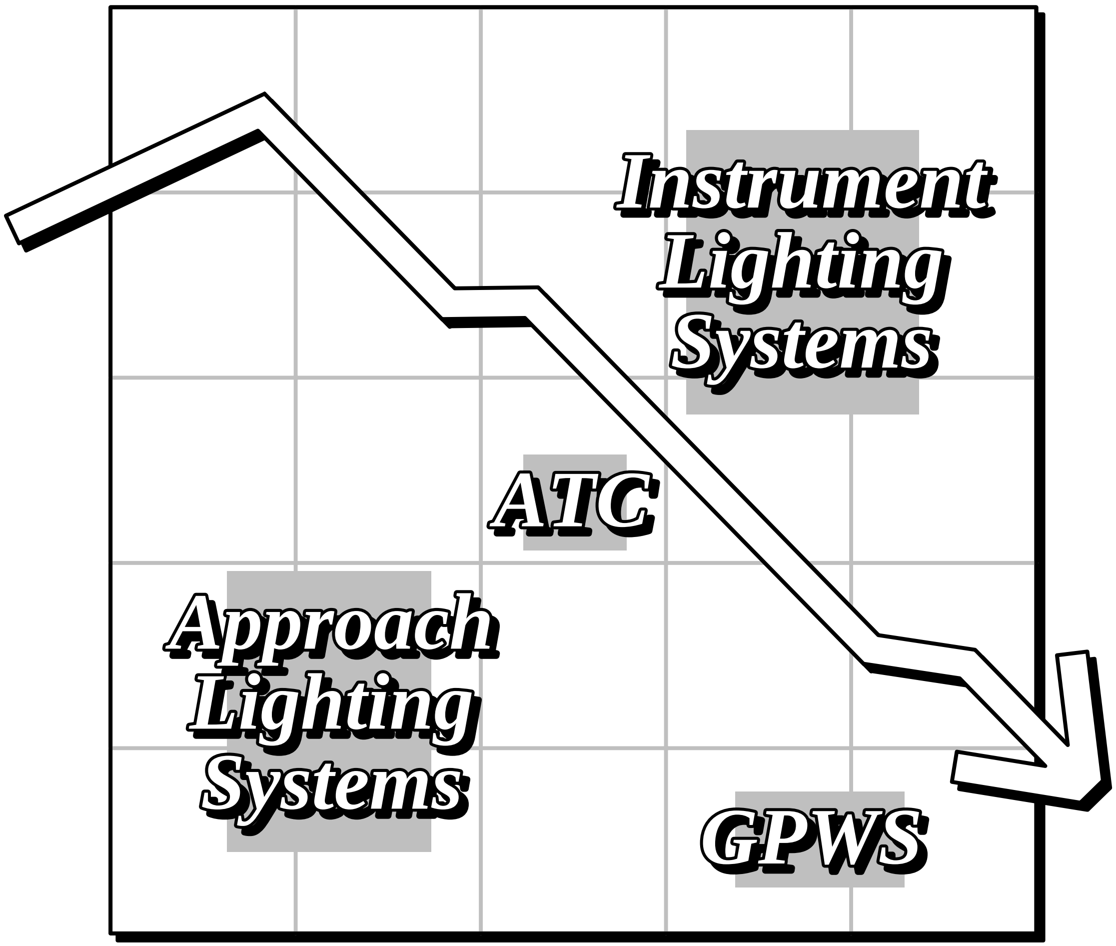


Figure 4-C.4

Worldwide CFIT accident data was not available until the mid-1960s. In the United States starting in 1975, large jet transport accidents attributed to CFIT fell to an average of only one every two years. A comparable reduction took place worldwide. A major reason for this was the advent of the Ground Proximity Warning System (GPWS). There were also other reasons for the reduction of accidents. Expansion and upgrading of Air Traffic Control (ATC) radar within the United States and installation of Approach Lighting Systems and Instrument Lighting Systems were some of the reasons for better flight safety. However, GPWS is generally accepted as making the biggest impact in reducing the number of CFIT accidents.

The most prevalent factor for hull losses with known causes is the flight crew. There are normally more CFIT accidents than any other type. The GPWS is the flight crew’s last chance to avoid an impact with the ground, water, or an obstacle. While this briefing will include information on the use of GPWS, it is logical to emphasize the causes and contributing factors of CFIT so that appropriate accident prevention strategies are developed. Hopefully, this will assist the flight crew in avoiding situations that force them to react to a GPWS escape warning.



Reasons for the Fall Of CFIT Accidents

Figure 4-C.5

There are two basic causes for CFIT accidents; both involve flight crew situational awareness. (One definition of situational awareness is an accurate perception by pilots of the factors and conditions currently affecting the safe operation of the aircraft and the crew).

The causes of CFIT are the flight crews' lack of vertical position awareness or their lack of horizontal position awareness in relation to the ground, water, or an obstacle. More than two-thirds of all CFIT accidents are the result of altitude error or lack of vertical situational awareness.

Simply stated, flight crews need to know where they are and the safe altitude to fly. It follows then that CFIT accidents occur during reduced visibility associated with instrument meteorological conditions (IMC), darkness, or a combination of both conditions.

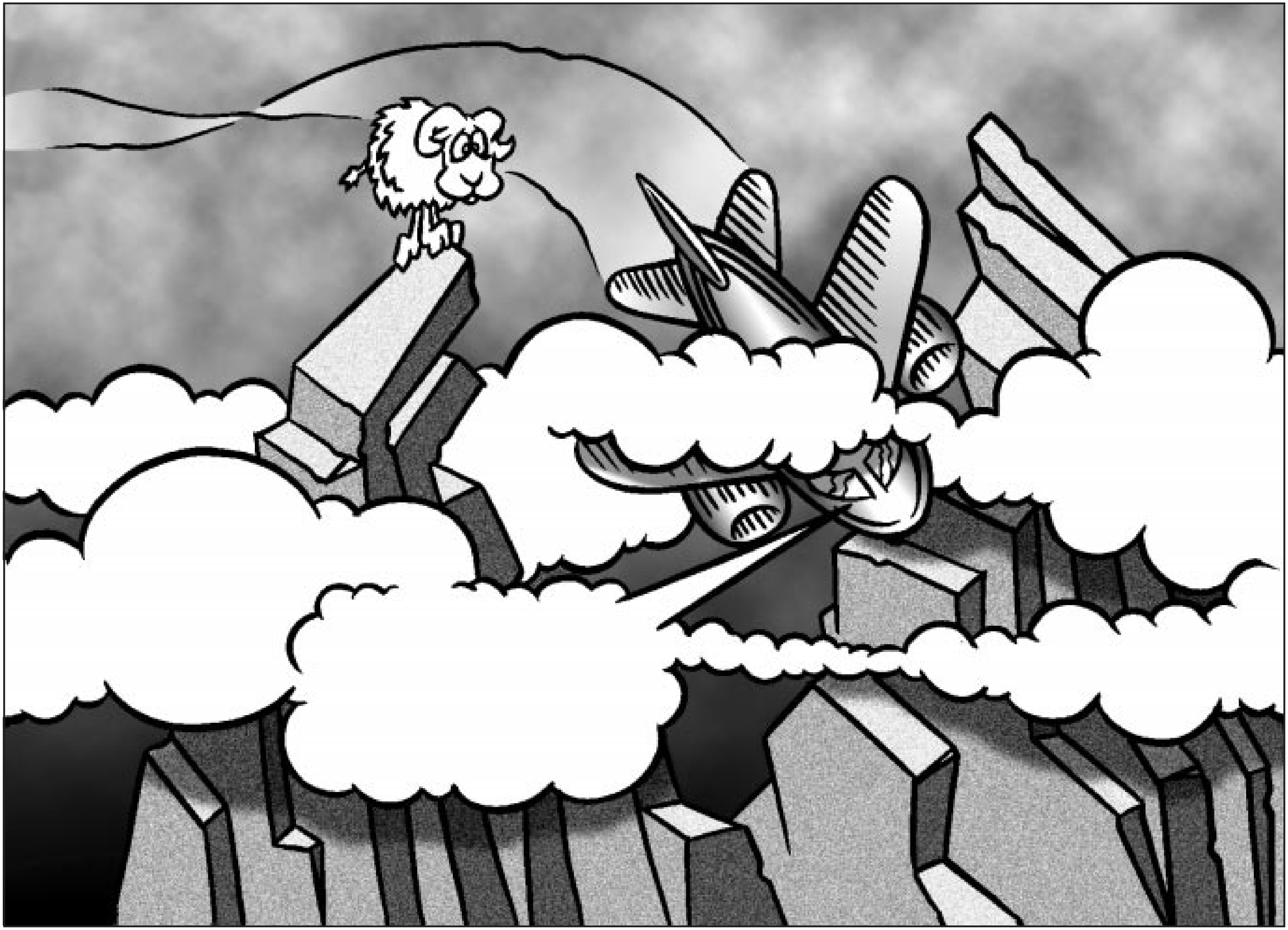


Figure 4-C.6

Factors That Contribute to CFIT

There are many factors that lead to CFIT accidents. We all accept that the pilot has the final responsibility for preventing a CFIT accident, but if many of the factors normally associated with these accidents were eliminated or at least mitigated, the potential for pilot errors would be lessened.

Each of these contributing factors will be discussed. Solutions to counter these factors will be included in the discussion.

Factors That Contribute to CFIT

- Altimeters
- Safe Altitude
- ATC
- Flight Crew Complacency
- Procedural
- Descent, Approach, and Landing
- Autoflight System
- Training

Figure 4-C.7

Accidents and numerous incidents have happened because of problems associated with the aircraft altimeter. These factors associated with altimeters can be grouped into two areas: altimeter units of measurement and altimeter settings.

While there is an international standard for units of measurement, it not adhered to by all countries. Settings may be given in inches of mercury, hectoPascals, or millibars. Additionally, some air traffic systems use meters and some use feet for altitude reference. The unit of measurement used depends on the area of the world in which the flight crew is flying. A problem can arise when the flight crew is trained and primarily operates in one area of the world and only periodically operates elsewhere.

Here is what can happen. An ATC controller, who speaks English as a second language, hurriedly advises the crew to descend and maintain 9,000 feet using an altimeter setting of “992”. The crew sets 29.92 inHg, not 992 hPa that the controller was expecting to be set. Throughout the approach the airplane will be approximately 600 feet below the altitude indicated on the altimeter. This can make the difference between a normal landing at the destination and an accident.

Prevention:

- Know what altimeter units of measurement are used for the area.
- Be vigilant during radio transmissions. Verify if in doubt.
- Be prepared to convert feet and meters.

Inches of Mercury

HectoPascals

Millibars

- **Know what altimeter units of measurement are used for the area.**
- **Be vigilant during radio transmission. Verify if in doubt.**
- **Be prepared to convert feet and meters.**

Figure 4-C.8

The QNH altimeter setting is obtained by measuring the existing surface pressure and converting it to a pressure that would theoretically exist at sea level at that point. This is accomplished by adding the pressure change for elevation above sea level on a standard day. This QNH altimeter setting is the standard used throughout most of the world. *Some states, however, report or use QFE.*

The QFE altimeter setting is the actual surface pressure and is not corrected to sea level. The QFE altimeter setting results in the altimeter indicating height above field elevation while the QNH setting results in the altimeter indicating height above mean sea level.

There have been incidents in which a QNH setting has been erroneously used as a QFE setting. This results in the airplane being flown at a lower than required altitude.

The QNE altimeter setting is always 29.92 inches of mercury, or 1013 hectopascals/millibars. QNE is set when operating at, climbing through, or operating above the transition altitude. Transition altitudes are not standardized throughout the world, which increases the potential for pilots to make errors.

Extreme atmospheric anomalies, such as low temperatures or low pressures, can affect altimeters and result in reduced altitude margins of safety.

It is easy to make mistakes with altimeters. For example, 28.82 inches of mercury is an unusually low setting. Pilots have erroneously set 29 instead of 28 because of the rare occurrences of such a low setting. They have formed a habit of using the “normal” 29. *This mistake will make you fly 1,000 feet lower than required!*

- **Know what altimeter units of measurement are used for the area.**
- **Know the phase of flight to apply the appropriate altimeter setting.**
- **Use altimeter setting cross-check and readback cockpit procedure.**
- **Cross-check radio altimeter and barometric altimeter readings.**
- **Operate at higher than minimum altitudes during atmospheric anomalies.**

Figure 4-C.9

Vertical awareness implies that pilots know the altitude relationship of the airplane to the surrounding terrain or obstacles. Obviously, during IMC and reduced visibility flight conditions, it is necessary to rely on altitude information provided by other than visual means. To assist pilots, instrument flight rule enroute charts and approach charts provide Minimum Safe Altitudes (MSA), Minimum Obstruction Clearance Altitudes (MOCA), Minimum Enroute Altitudes (MEA), Emergency Safe Altitudes (EAS), and in most terminal areas, actual heights of the terrain or obstacles. Traditional maps, such as Sectional or Operational Navigation Charts, are available for more detailed study. The potential for CFIT is greatest in the terminal areas. Detailed altitude information is provided to assist the pilot in maintaining situational awareness.

- Make sure adequate charts are available.
- Study the altitude information.
- Know and fly at or above the safe altitudes for your area of operation.

[Optional supporting information]

A pilot on a flight to Portland, Oregon, USA, made this report. “The area below us was like a ‘black hole’ because of forest and it was unpopulated. The city lights were off the right wing—a beautiful night. After being cleared for a visual approach, I began descent so as to arrive... at the recommended 3,000 feet mean sea level. ...At 4,100 feet MSL, the GPWS went‘Whoop, whoop! Pull up! Terrain.’ For a split second we thought it was a false warning, since we were still looking at the airport/city. Then I noticed both radio altimeters go from 2,500 feet to 400 feet in 1-2 seconds. I immediately applied full power and initiated a max climb until over the city’s outskirts (lights). Our whole crew serves this city daily and knows the airport well. Simple fact is that most pilots going into a familiar airport use the approach plate and do not often refer to the area chart. ...We were stupid and very lucky.” (Source: ASRS report 216837.)

- **Make sure adequate charts are available.**
- **Study the altitude information.**
- **Know and fly at or above the safe altitudes for your area of operation.**

Figure 4-C.10

The inability of air traffic controllers and pilots to properly communicate has been a factor in many CFIT accidents. There are multiple reasons for this problem. With the growth of the aviation industry taking place throughout the world, the use of English as a common language is more difficult to support. The lack of English language proficiency can make understanding controller instructions to the pilots and airborne information or requests from the pilots to the controllers much more prone to error. Heavy workloads can lead to hurried communications and the use of abbreviated or non-standard phraseology. The potential for instructions meant for one airplane and given to another is increased. Unreliable radio equipment still exists in some areas of the world, which compounds the communication problems.

- Make sure adequate charts are available.
- Study the altitude information.
- Know and fly at or above the safe altitudes for your area of operation.

[Optional supporting information]

The importance of good communications was pointed out in a report by an air traffic controller and flight crew of an MD-80. The controller reported that he was scanning his radar scope for traffic and noticed that the MD-80 was descending through 6,400 ft and immediately instructed a climb to at least 6,500 ft. The pilot responded that he had been cleared to 5,000 ft and then climbed to…The pilot reported that he had “heard” a clearance to 5,000 ft and read back 5,000 ft to the controller and received no correction from the controller. After almost simultaneous GPWS and controller warnings, the pilot climbed and avoided the terrain. The recording of the radio transmissions confirmed that the airplane was cleared to 7,000 ft and the pilot mistakenly read back 5,000 ft and attempted to descend to 5,000 ft. The pilot stated in the report: “I don’t know how much clearance from the mountains we had, but it certainly makes clear the importance of good communications between the controller and pilot.” (Source: ASRS report 96032)

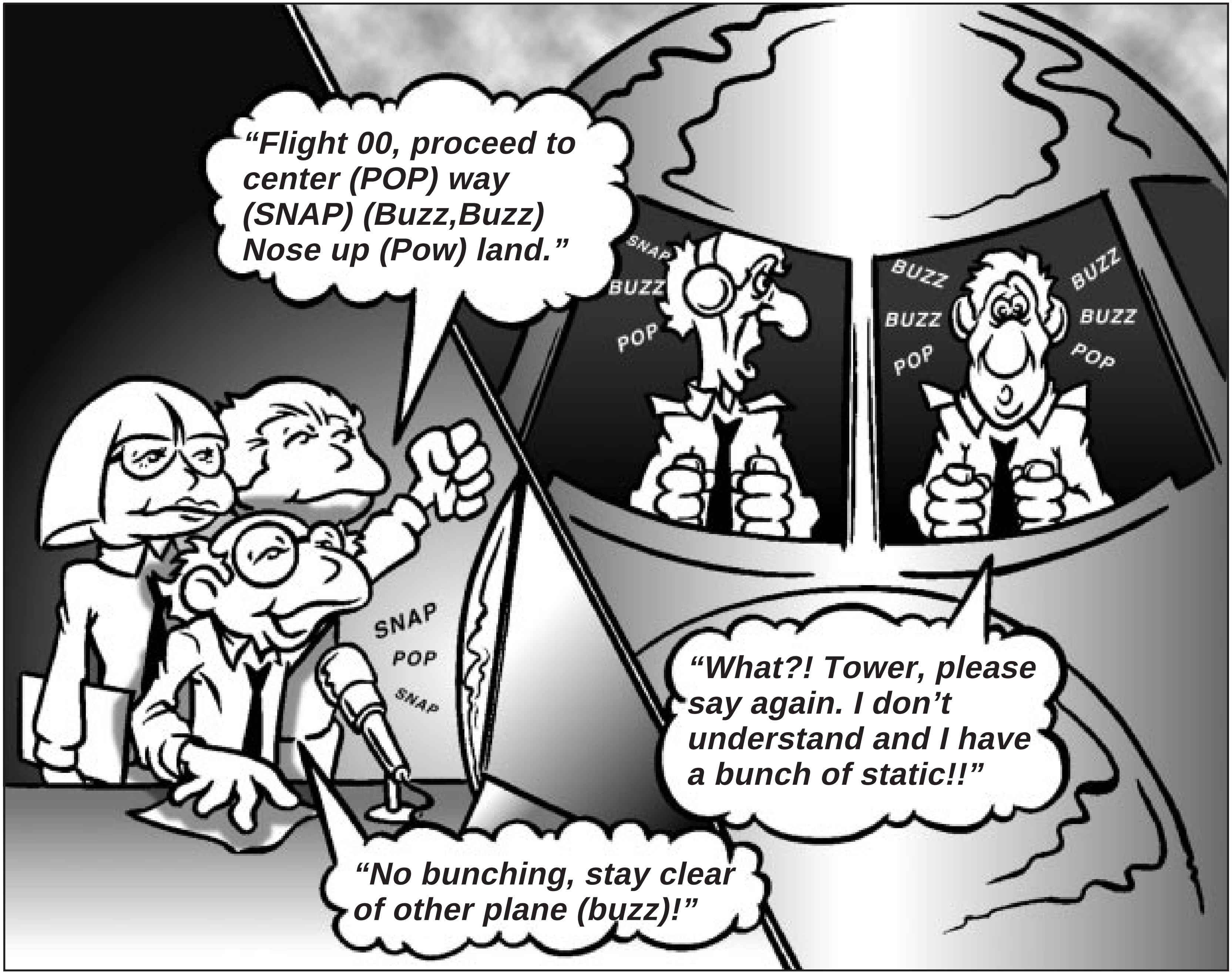
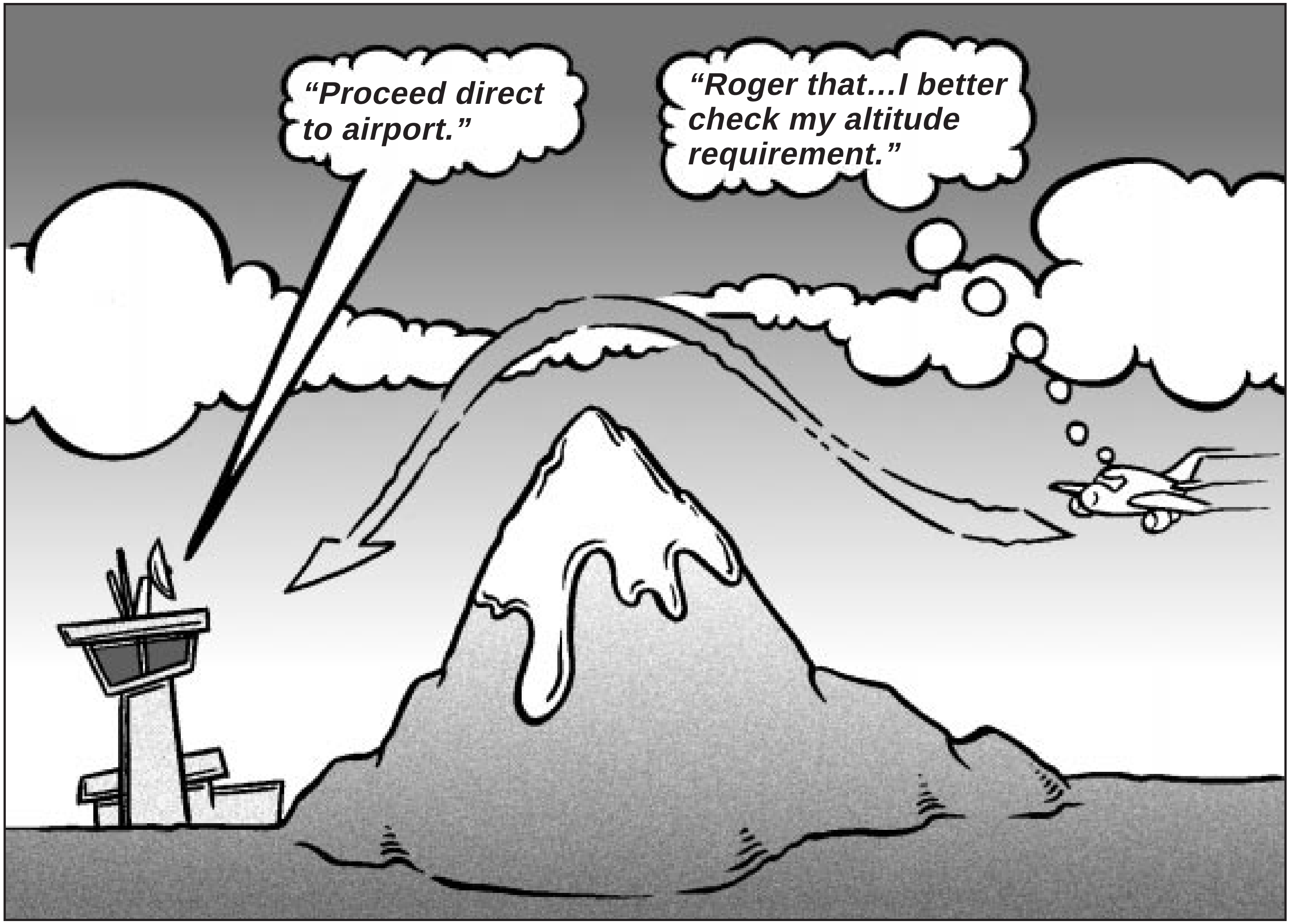

"Flight 00, proceed to center (POP) way (SNAP) (Buzz,Buzz) Nose up (Pow) land."
SNAP
BUZZ
POP
BUZZ
BUZZ
POP
BUZZ
BUZZ
POP
SNAP
POP
SNAP
"What?! Tower, please say again. I don't understand and I have a bunch of static!!"
"No bunching, stay clear of other plane (buzz)!"

Figure 4-C.11

ATC is not always responsible for safe terrain clearance for the airplanes under its jurisdiction. *Many times ATC will issue enroute clearances for pilots to proceed off airway direct to a point. When pilots accept this clearance, they also accept responsibility for maintaining safe terrain clearance.*

- Exercise good radio communication discipline.
- Know the height of the highest terrain or obstacle in the operating area.
- Know your position in relation to the surrounding high terrain.

Airspace constraints that are most prevalent in the terminal areas many times require air traffic controllers to radar vector airplanes at minimum vectoring altitudes that can be lower than the sector Minimum Safe Altitude. Proper vertical and horizontal situational awareness is vital during this critical phase of flight. Humans make errors. From time to time, ATC may issue flawed instructions that do not ensure adequate terrain clearance. While it may be difficult for flight crews to know that an error has been made, it is possible that the mistake can be detected with good pilot position and altitude awareness.



- **Exercise good radio communication discipline.**
- **Know the height of the highest terrain or obstacle in the operating area.**
- **Know your position in relation to the surrounding high terrain.**

Figure 4-C.12

- Challenge or refuse ATC instructions when they are not clearly understood, are questionable, or conflict with your assessment of airplane position relative to the terrain.
- Know the height of the highest terrain or obstacle in the operating area.
- Know your position in relation to the surrounding high terrain.

[Optional supporting information]

“While in a left turn to 330 degrees after takeoff, combined tower/departure controller said: ‘Radar contact, turn left heading 300 degrees.’ We responded by acknowledging the heading and ‘leaving 6 for 7,000 feet. Aircraft was leveled off at 7,000 feet MSL. Captain asked controller the elevation of the terrain below us. Tower replied: ‘5,800 feet’. After approximately one minute level at 7,000 feet MSL, the radar altimeter light came on indicating terrain less than 2,500 feet. A climb was immediately initiated when the GPWS warned: ‘Terrain, Terrain.’ ATC was advised we‘re climbing. ATC replied: ‘Verify you’re climbing to 17,000.’ Captain replied that we’re issued 7,000 feet. ATC replied: ‘climb and maintain 17,000.’...The controller said he was the new shift replacement for the controller who had given us the clearance.” (Source: ASRS 95474.)

Complacency can be defined as self-satisfaction, smugness, or contentment. You can understand why after years in the same flight deck, on the same route structure to the same destinations, a pilot could become content, smug, or self-satisfied. Add to this equation a modern flight deck with a well functioning autopilot, and you have the formula for potential complacency.

Flight crews may also be exposed to continued false GPWS warnings because of a particular terrain feature and a GPWS

- **Challenge or refuse ATC instructions when they are not clearly understood, are questionable, or conflict with your assessment of airplane position relative to the terrain.**
- **Know the height of the highest terrain or obstacle in the operating area.**
- **Know your position in relation to the surrounding high terrain.**

Figure 4-C.13

database that has not been customized for the arrival. The flight crew becomes conditioned to this situation, since they have flown the approach many times. This can also lull the flight crew into complacency, and they may fail to react to an actual threat. Note: The newer versions of GPWS can be programmed by the manufacturer for specific airfield approach requirements so that these nuisance warnings are eliminated.

- Know that familiarity can lead to complacency.
- Do not assume that this flight will be like the last flight.
- Adhere to procedures.

Many studies show that operators with established, well thought out and implemented standard operating procedures (SOP) consistently have safer operations. It is through these procedures that the operator sets the standards that all flight crews are expected to follow.

CFIT accidents have happened when flight crews did not know the procedures, did not understand them, or did not

- **Know that familiarity can lead to complacency.**
- **Do not assume that this flight will be like the last flight.**
- **Adhere to procedures.**

Figure 4-C.14

comply with them, or when there were no procedures established. In the absence of standard operating procedures, flight crews will establish their own to fill the void in order to complete the flight. Some flight crews think the weather is never too bad to initiate an approach! It is the responsibility of management to develop the comprehensive procedures, train the flight crews, and quality control the results.

It is the responsibility of the flight crew to learn and follow the procedures and provide feedback to management when the procedures are incorrect, inappropriate, or incomplete.

- Do not invent your own procedures.
- Management must provide satisfactory standard operating procedures and provide effective training to the flight crew.
- Comply with these procedures.

CFIT accidents have occurred during departures, but the overwhelming majority of accidents occur during the descent, approach, and landing phases of the flight. CFIT accidents make up the majority of these accidents.

An analysis of 40 CFIT accidents was accomplished for a 5-year period, 1986 to 1990. The airplanes' lateral and vertical

- **Do not invent your own procedures.**
- **Management must provide satisfactory standard operating procedures and provide effective training to the flight crew.**
- **Comply with these procedures.**

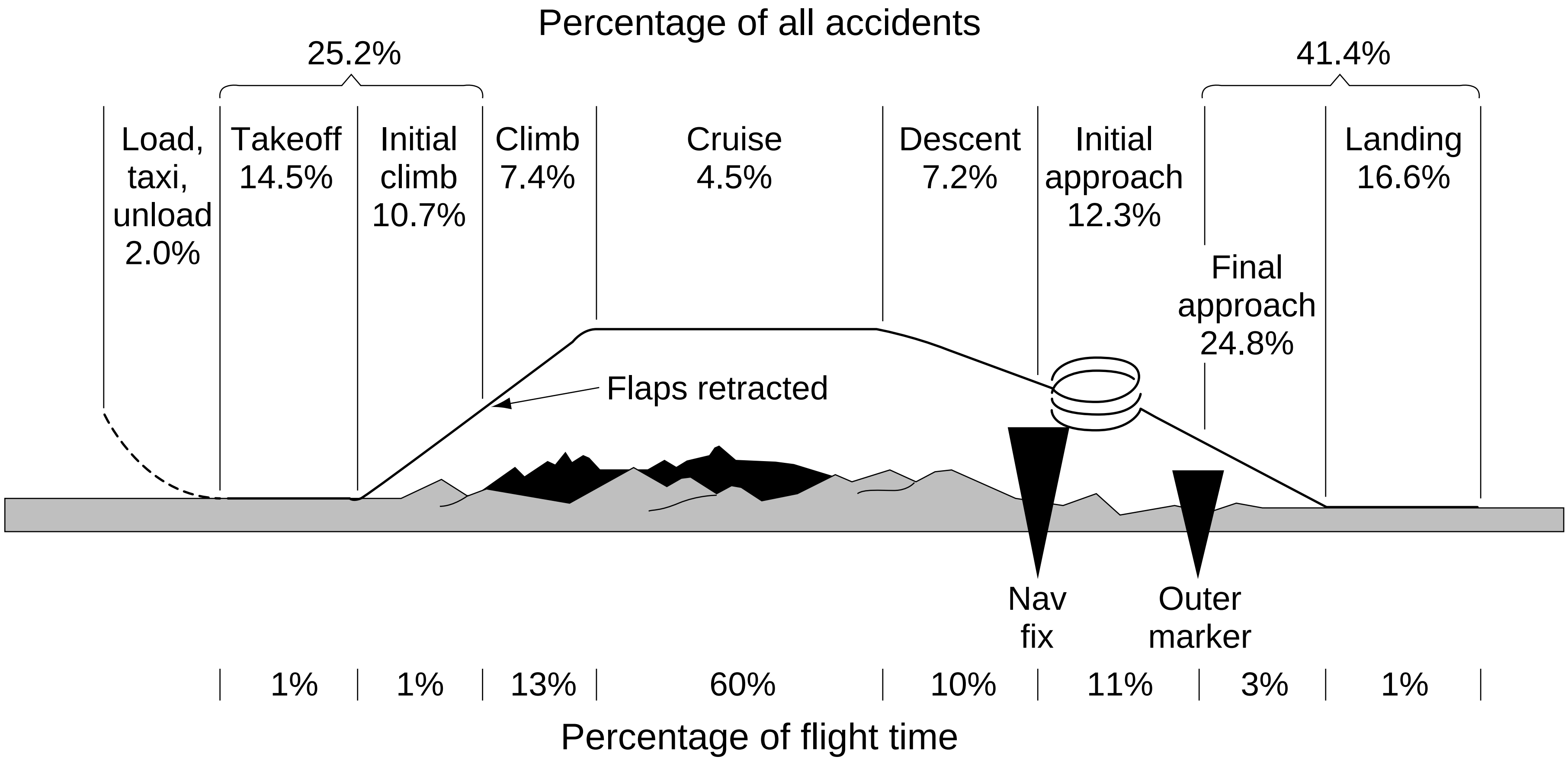
Figure 4-C.15

positions were plotted in relation to the airport runway. Almost all the position plots are on the runway centerline inside of 10 miles from the intended airport. The vertical profiles showed flight paths at a relatively constant 3 degrees, but right into the ground!

The geographical location of CFIT accidents during the 1970s show a different pattern than those in the late 1980s and 1990s. During the five-year period from 1972 through 1977, there were 75 CFIT accidents or incidents. Twenty-five of these accidents/incidents were greater than 8 nautical miles from the runway. The preponderance of the remaining accidents/incidents were inside the middle marker. However, for the period 1986 to 1990, the distribution of accidents/incidents was relatively even. This difference may be the result of improvements made in runway approach aids that took place during this time period. Additional Instrument Landing Systems were installed, as well as runway approach lighting systems.

- Know what approach and runway aids are available before initiating an approach.
- Use all available approach and runway aids.
- Use every aid to assist you in knowing your position and knowing the required altitudes at that position.

Most CFIT accidents occur during nonprecision approaches, specifically VOR/DME approaches. Inaccurate or poorly designed approach procedures, coupled with a variety of depictions, can be part of the problem.



- **Know what approach and runway aids are available before initiating an approach.**
- **Use all available approach and runway aids.**
- **Use every aid to assist you in knowing your position and knowing the required altitudes at that position.**

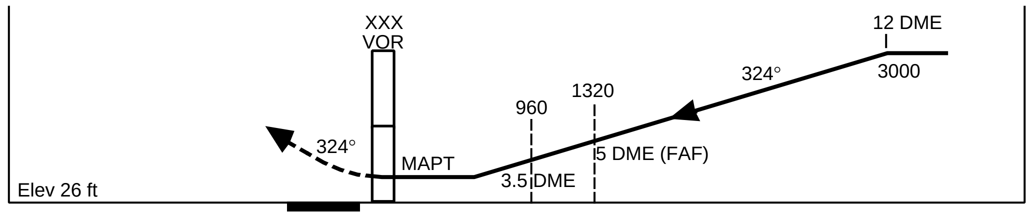
Figure 4-C.16

This is an example of an approach procedure produced by different sources. There are documented cases that the minimum terrain clearances on some published approach charts have contributed to both accidents and incidents. For more than a decade, a worldwide effort has been underway to both raise and standardize the descent gradient of non-precision approaches. There are gradients as little as 0.7 degrees in some VOR approach procedures.

In addition to the shallow approach gradients, many approaches use multiple altitude step-down procedures. This increases the pilot workload and the potential for making errors.

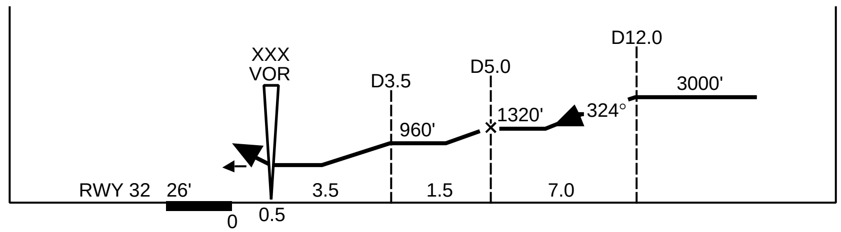
- Study the approach procedure(s) before departure.
- Identify unique gradient and step-down requirements.
- Review approach procedures during approach briefing.
- Use autoflight systems, when available.

There is more than one standard for approach procedures in the world. The United States standard is Terminal Instrument Procedures (TERPS). The ICAO standard is Procedures for Air Navigation Services-Aircraft Operations (PANS-OPS),

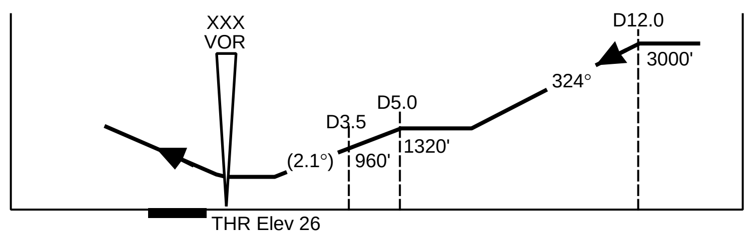


State AIP

- Many ways to present the descent profile
- Comparison of profiles for the same



Commercial Source A



Commercial Source B

- **Study the approach procedure(s) before departure.**
- **Identify unique gradient and step-down requirements.**
- **Review approach procedures during approach briefing.**
- **Use autoflight systems, when available.**

Figure 4-C.17

and the Russian Federation uses still another. Flight crews, therefore, may be exposed to different standards and different margins of safety.

- Study anticipated approach procedures before departure.
- Know that there are different approach design standards.

Unstable approaches contribute to many CFIT accidents or incidents. Unstable approaches increase the possibility of

- Study anticipated approach procedures before departure.
- Know that there are different approach design standards.

Figure 4-C.18

diverting a pilot's attention away from the approach procedure to regain better control of the airplane. A stabilized approach is defined by many operators as a constant rate of descent along an approximate 3 degree flight path with stable airspeed, power setting, and trim, with the airplane configured for landing.

Use the display and control modes recommended for the type of approach being flown, and as specified in the standard operating procedures applicable to the airplanes type. Be aware of the limitations associated with the specified procedures.

- Fly stabilized approaches.
- Execute a missed approach if not stabilized by 500 feet above ground level or an altitude specified by your SOP.

A minimum of three to five near collision with the terrain autoflight-related incidents occur each year. Not all incidents

- **Fly stabilized approaches.**
- **Execute a missed approach if not stabilized by 500 feet above ground level or an altitude specified by your SOP.**

Figure 4-C.19

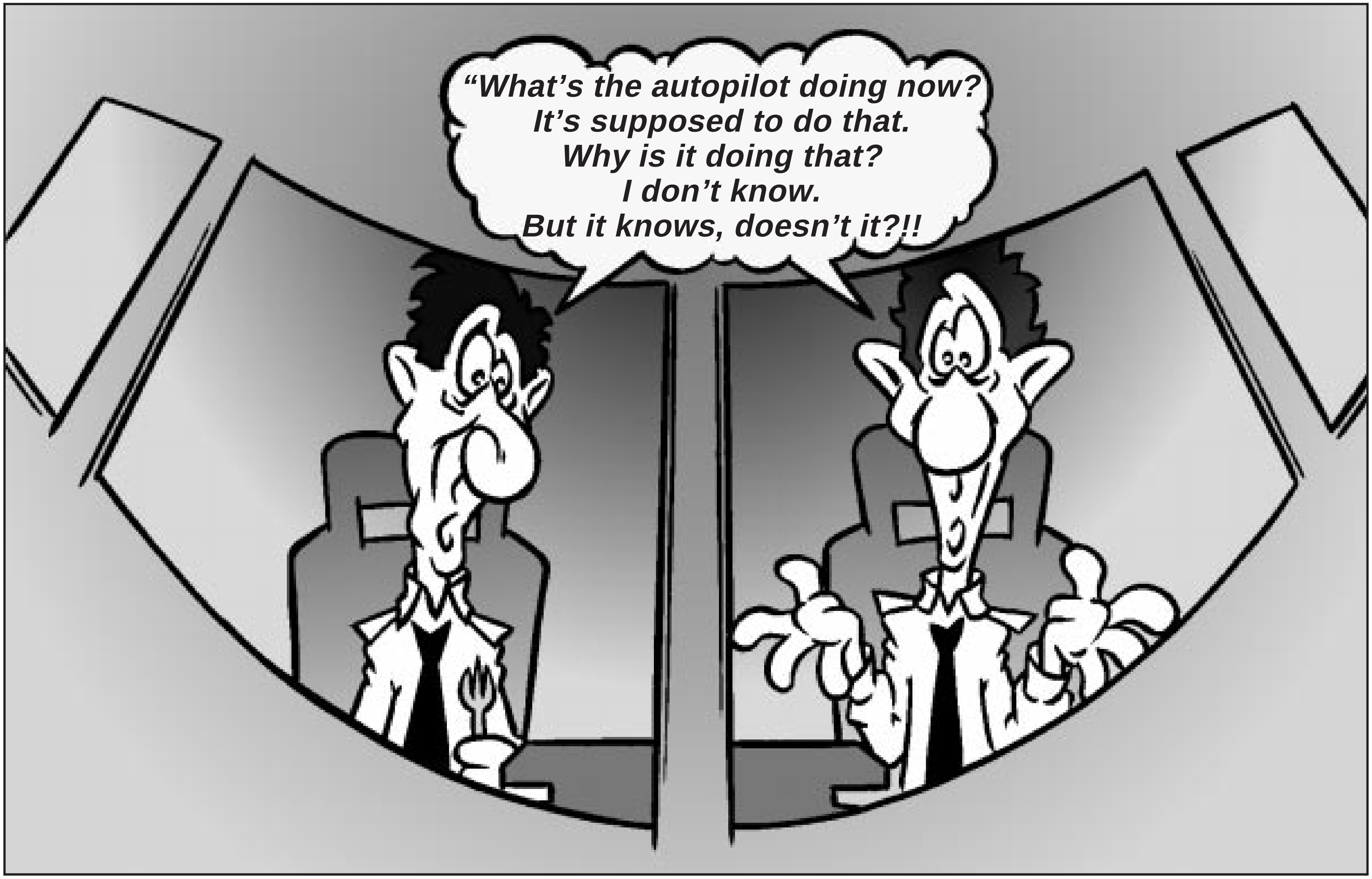
are reported. The actual number of incidents may be much greater. The advancement of technology in today's modern airplanes has brought us flight directors, autopilots, autothrottles and flight management systems. All of these devices are designed to reduce pilot workload. They keep track of altitude, heading, airspeed, and the approach flight path, and they tune navigation aids with unflagging accuracy. When used properly, this technology has made significant contributions to flight safety. But technology can increase complexity and also lead to unwarranted trust or complacency.

Autoflight systems can be misused, contain database errors, or be provided with faulty inputs by the flight crew. They will sometimes do things that the flight crew did not intend for them to do.

- Monitor the autoflight system for desired operation.
- Avoid complacency.
- Follow procedures.
- Cross-check raw navigation information.

[Optional supporting information]

Imagine this situation. You are descending, and the autoflight system is engaged and coupled to fly the FMC course. It is night time, and you are flying an instrument arrival procedure in mountainous terrain. The FMC has been properly programmed, and the airplane is on course when ATC amends the routing. In the process of programming the FMC, an erroneous active waypoint is inserted. While you and the first officer are reconciling the error, the airplane begins a turn to the incorrect waypoint! It does not take very long to stray from the terrain-altitude-protected routing corridor.

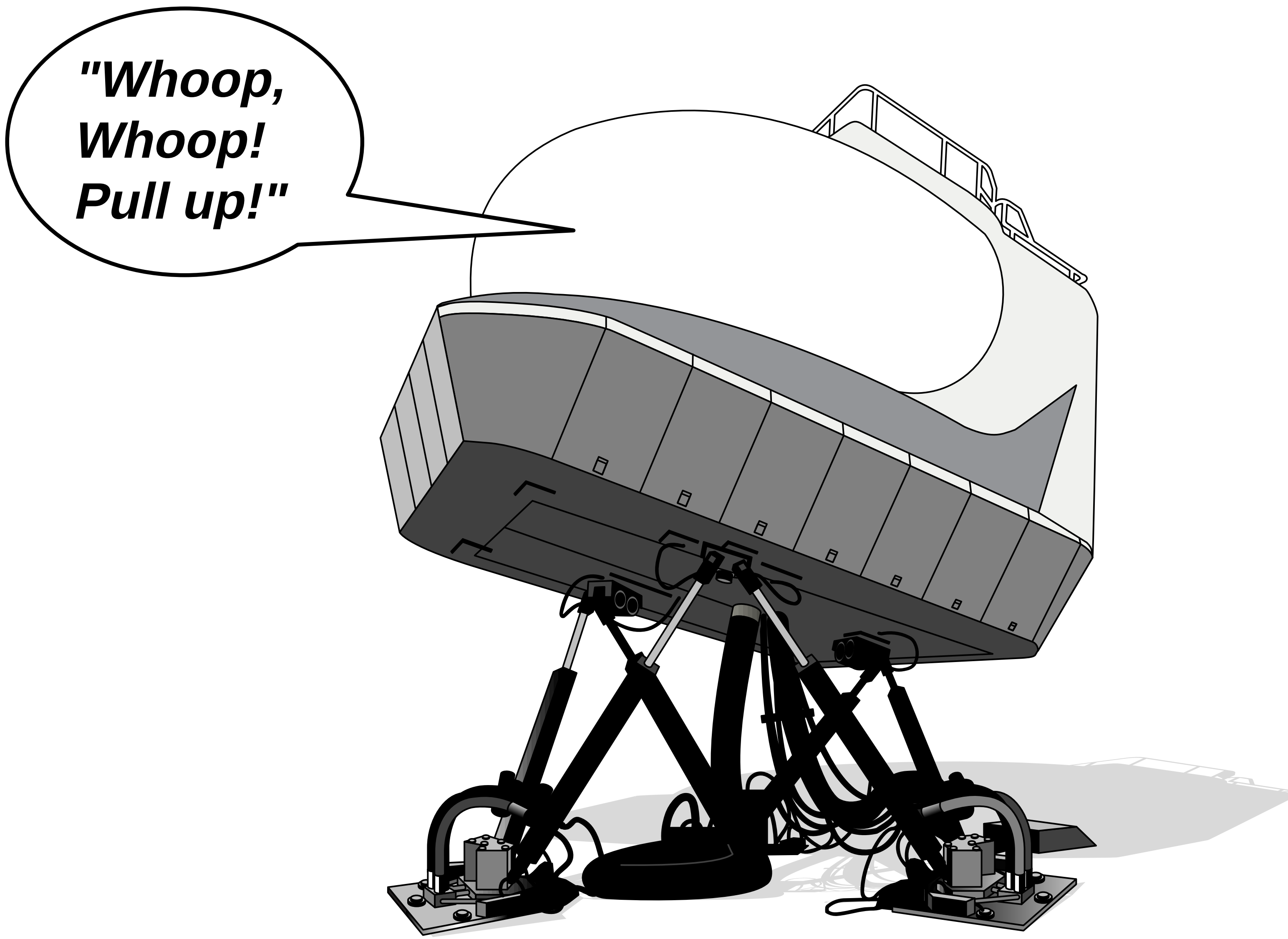


- **Monitor the autoflight system for desired operation.**
- **Avoid complacency.**
- **Follow procedures.**
- **Cross-check raw navigation information.**

Figure 4-C.20

Most of the factors that have been identified are the result of deficiencies in flight crew training programs. Therefore, training becomes a significant factor that contributes to CFIT. Well-designed equipment, comprehensive operating procedures, extensive runway approach aids, and standardized charting or altimeter setting procedures and units of measurement will not prevent CFIT unless flight crews are properly trained and disciplined.

- Develop and implement effective initial and recurrent flight crew training programs that consider CFIT.
- Implement Flight Operations Quality Assurance Programs.



- **Develop and implement effective initial and recurrent flight crew training programs that consider CFIT.**
- **Implement Flight Operations Quality Assurance Programs.**

Figure 4-C.21

In Section 2 of the CFIT Education and Training Aid (the Decision Makers Guide), we pointed out that CFIT prevention encompasses more than operator-related actions. There are system-related problems that, when solved, will help operators avoid situations that may lead to CFIT. Some progress has been made in solving the systemic problems, but much more needs to be done. In the meantime, operators can also do much more to prevent CFIT accidents.

- Crew briefings
- Autoflight systems
- Route and destination familiarization programs
- Altitude awareness techniques and procedures
- Callouts
- GPWS escape maneuvers
- Better charts
- Better training

Figure 4-C.22

Many of the CFIT accidents show a lack of flight crew communication. For example, while one pilot flew the approach, the other did not know or understand the intentions of the flying pilot. This lack of communication can lead to breakdowns in flight crew coordination and cross-checking. *One of the best ways to let the nonflying pilot know what to expect is to conduct a briefing before each takeoff and each approach.* While this seems elementary, many pilots simply ignore the obvious safety implications of the briefing.

Operators should require briefings by the flight crew. As operations vary from country to country, some briefing items may be more important than others and some unique items may be added, but there are some items that should always be covered.


"Don't forget your briefing before you take off and before you land.

Figure 4-C.23

Use the following takeoff briefing guidelines if other guidance is not provided by standard operating procedures or the airplane manufacturer.

- Weather at the time of departure.
- Runway in use, usable length (full length or intersection takeoff).
- Flap setting to be used for takeoff.
- V speeds for takeoff.
- Expected departure routing.
- Airplane navigation aids setup.
- Minimum sector altitudes and significant terrain or obstacles relative to the departure routing.
- Rejected takeoff procedures.
- Engine failure after V1 procedures.
- Emergency return plan.

Takeoff Briefing

- Weather at the time of departure.
- Runway in use, usable length (full length or intersection takeoff).
- Flap setting to be used for takeoff.
- V speeds for takeoff.
- Expected departure routing.
- Airplane navigation aids setup.
- Minimum sector altitudes and significant terrain or obstacles relative to the departure routing.
- Rejected takeoff procedures.
- Engine failure after V1 procedures.
- Emergency return plan.

Figure 4-C.24

The accident statistics show that the vast majority of accidents occur during the approach at the destination airport. Is it not logical then to prepare carefully and properly for the arrival, approach, and landing? *The approach briefing sets the professional tone for your safe arrival at the destination.* The flying pilot should discuss how he or she expects to navigate and fly the procedure. This will not only solidify the plan for the approach, but it will inform the nonflying pilot of intentions, which provides a basis for monitoring the approach. Deviations from the plan now can be more readily identified by the nonflying pilot. The approach briefing should be completed before arriving in the terminal area, so that both pilots can devote their total attention to executing the plan.

Use the following approach briefing guidelines if other guidance is not provided by standard operating procedures or the airplane manufacturer.

Approach Briefing

- Expected arrival procedure to include altitude and airspeed restrictions.
- Weather at destination and alternate airports.
- Anticipated approach procedure to include:
  - Minimum sector altitudes.
  - Airplane navigation aids setup.
  - Terrain in the terminal area relative to approach routing.
  - Altitude changes required for the procedure.
  - Minimums for the approach DA/H or MDA/H.
  - Missed approach procedure and intentions.
- Communication radio setup
- Standard callouts to be made by the nonflying pilot.

Figure 4-C.25

Proper use of the modern autoflight systems reduces workloads and significantly improves flight safety. These systems keep track of altitude, heading, airspeed, and flight paths with unflagging accuracy. Unfortunately, there are a great number of first-generation airplanes that are still operating that do not have the advantages associated with well-designed integrated systems. There are also some flight crews whose airplanes do have modern systems, but who do not take full advantage of the autoflight system to manage the progress of the flight and reduce workload.

To assist in preventing CFIT, the proper use of autoflight systems is encouraged during all approaches and missed approaches, in IMC, when suitable equipment is installed.

It is incumbent on operators to develop specific procedures for the use of autopilots and autothrottles during precision approaches, nonprecision approaches and missed approaches, and to provide simulator-based training in the use of these procedures for all flight crews.

Figure 4-C.26

Flight crews must be adequately prepared for CFIT critical conditions, both enroute and at the destination. *Flight crews must be provided with adequate means to become familiar with enroute and destination conditions for routes deemed CFIT critical*. One or more of the following methods are considered acceptable for this purpose:

- When making first flights along routes, or to destinations, deemed CFIT critical, Captains should be accompanied by another pilot familiar with the conditions; or,
- Suitable simulators can be used to familiarize flight crews with airport critical conditions when those simulators can realistically depict the procedural requirements expected of flight crew members; or,
- Written guidance, dispatch briefing material, and video familiarization using actual or simulated representations of destination and alternatives should be provided.

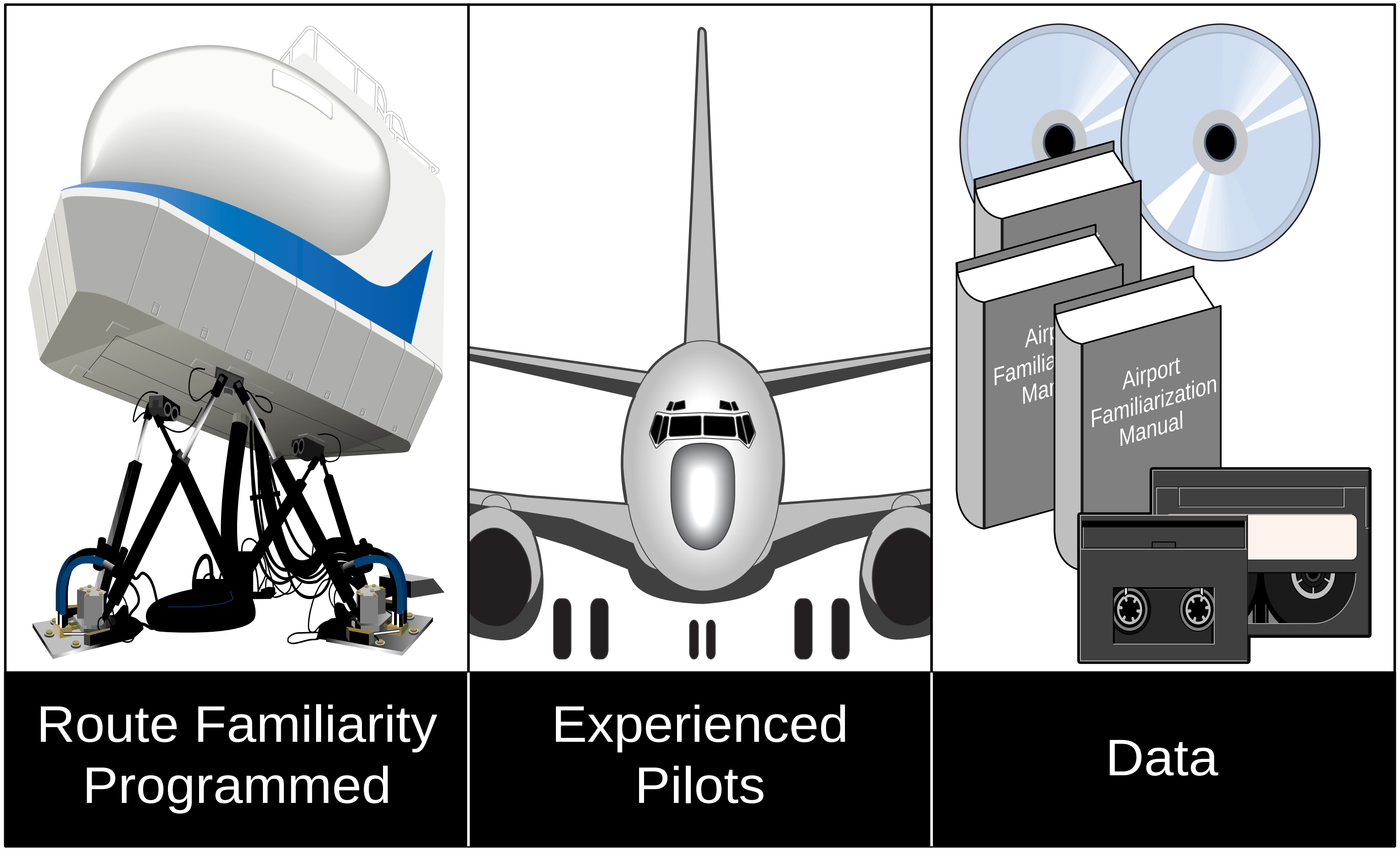

Airport Familiarization Manual
Route Familiarity Programmed
Experienced Pilots
Data

Figure 4-C.27

It is essential that flight crews always appreciate the altitude of their airplane relative to terrain, and the assigned or desired flight path. Flight crews need to be provided with and need to use procedures with which they will monitor and cross-check assigned altitudes, as well as verify and confirm altitude changes. As a minimum, in the absence of standard operating procedures or airplane manufacturer's guidance, use the following procedures:

- Ascertain the applicable MSA reference point. Note: The MSA reference point for an airport may vary considerably according to the specific approach procedure in use.

- Know the applicable transition altitude or transition level.

- Use a checklist item to ensure that all altimeters are correctly set in relation to the transition altitude/level. Confirm altimeter setting units by repeating all digits and altimeter units in clearance readbacks and intracockpit communications.

- Call out any significant deviation or trend away from assigned clearances.

- Include radio height in the pilot instrument scan.

- Upon crossing the final approach fix, outer marker, or equivalent position, the pilot not flying will cross-check actual crossing altitude/height against altitude/height as depicted on the approach chart.

- Follow callout procedures.

Altitude Awareness

- Ascertain the applicable MSA reference point. Note: The MSA reference point for an airport may vary considerably according to the specific approach procedure in use.
- Know the applicable transition altitude or transition level.
- Use a checklist item to ensure that all altimeters are correctly set in relation to the transition altitude/level. Confirm altimeter setting units by repeating all digits and altimeter units in clearance readbacks and intracockpit communications.
- Call out any significant deviation or trend away from assigned clearances.
- Include radio height in the pilot instrument scan.
- Upon crossing the final approach fix, outer marker, or equivalent position, the pilot not flying will cross-check actual crossing altitude/height against altitude/height as depicted on the approach chart.
- Follow callout procedures.

Figure 4-C.28

Callouts are defined as aural announcements, by either flight crew members or airplane equipment, of significant information that could affect flight safety. A callout should be made at the following times:

- Upon initial indication of radio altimeter height, at which point altitude versus height above terrain should be assessed and confirmed to be reasonable.
- When the airplane is approaching from above or below the assigned altitude (adjusted as required to reflect specific airplane performance).
- When the airplane is approaching relevant approach procedure altitude restrictions and minimums.
- When the airplane is passing transition altitude/level.

Callouts

- Upon initial indication of radio altimeter height, at which point altitude versus height above terrain should be assessed and confirmed to be reasonable.
- When the airplane is approaching from above or below the assigned altitude (adjusted as required to reflect specific airplane performance).
- When the airplane is approaching relevant approach procedure altitude restrictions and minimums.
- When the airplane is passing transition altitude/level.

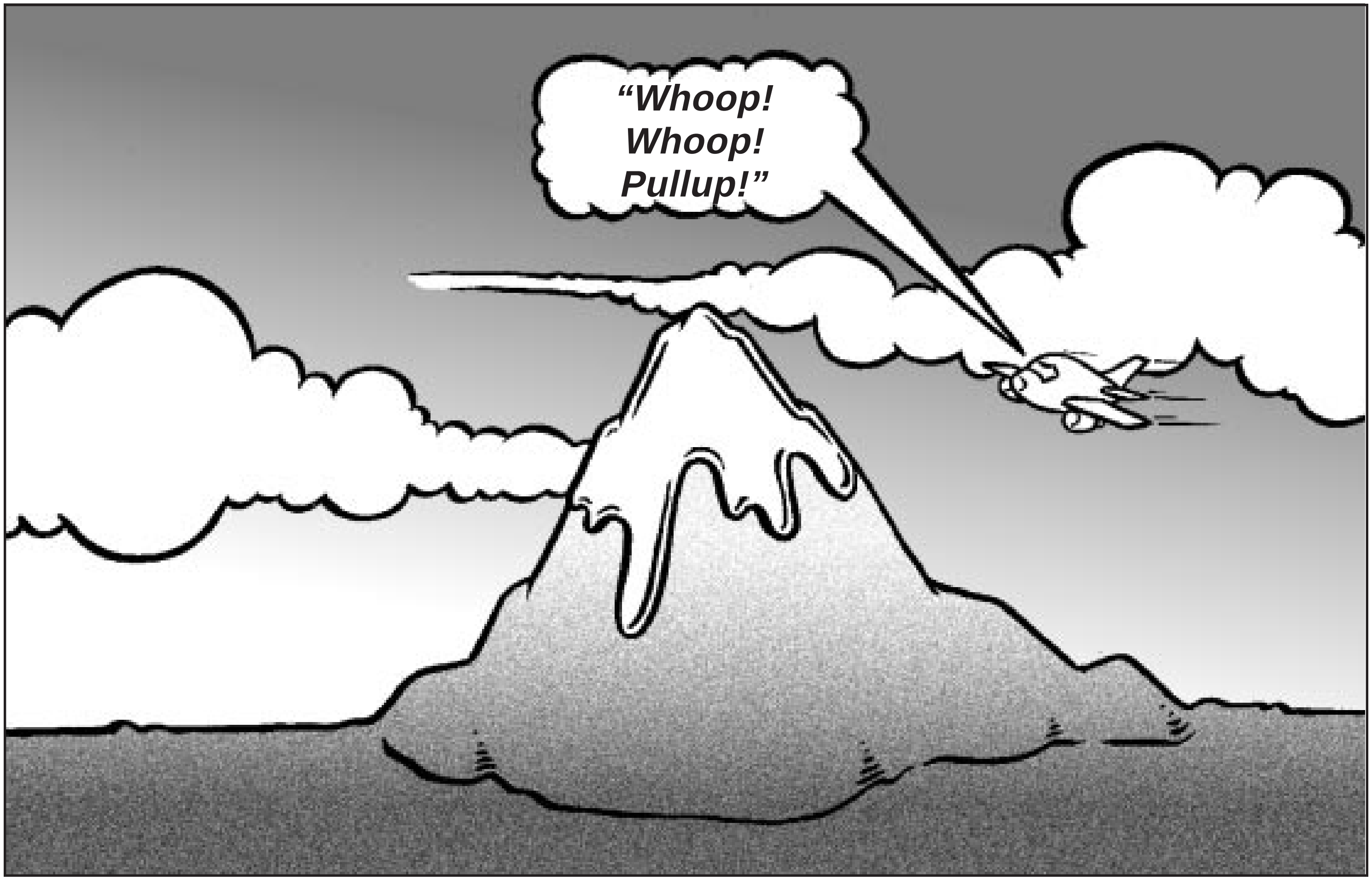
Figure 4-C.29

The GPWS warning is normally the flight crew's last opportunity to avoid CFIT. Incidents and accidents have occurred because flight crews have failed to make timely and correct responses to the GPWS warnings. The available time has increased between initial warning and airplane impact since the first version of the GPWS; however, this time should not be used to analyze the situation. React immediately. With the early versions, there was as little as 5 seconds warning, and none at all if the impact point was on a relatively steep slope of a mountain. There may be as much as 30 seconds for newer and future versions.

In the absence of standard operating procedures or airplane manufacturer guidance, execute the following maneuver in response to a GPWS warning, except in all but clear daylight VMC, when the flight crew can immediately and unequivocally confirm that an impact with the terrain, water, or obstacle will not take place:

- React immediately to a GPWS warning.
- Positively apply maximum thrust, and rotate to the appropriate pitch attitude for your airplane.
- Pull up with wings level to ensure maximum airplane performance.
- Always respect stick shaker.

Continue the escape maneuver until climbing to the sector emergency safe altitude or until visual verification can be made that the airplane will clear the terrain or obstacle, even if the GPWS warning stops.



- React immediately to a GPWS warning.
- Positively apply maximum thrust, and rotate to the appropriate pitch attitude for your airplane.
- Pull up with wings level to ensure maximum airplane performance.
- Always respect stick shaker.

Figure 4-C.30

Flight crews must be provided with and must be trained to use adequate navigation and approach charts that accurately depict hazardous terrain and obstacles. These depictions of the hazards must be easily recognizable and understood. On modern technology airplanes, the electronic displays should resemble printed chart displays to the maximum extent feasible.

Flight crew training can be a contributing factor to CFIT. It is also the key to CFIT accident prevention. Modern airplane equipment, extensive standard operation procedures, accurate charts, improved approach procedures, detailed checklists, or recommended avoidance techniques will not prevent CFIT if flight crews are not adequately trained. The cause of CFIT is the flight crew’s lack of vertical and/or horizontal situational awareness. We know the solutions to these causes: a proper support infrastructure and a trained and disciplined flight crew.

Figure 4-C.31

In the previous discussion, the causes of CFIT and contributing factors were identified, along with recommendations and strategies that may be used to avoid CFIT accidents and incidents. It could be misleading to the reader when causes and factors are discussed separately.

Accidents and incidents do not normally happen because of one decision or one error. They rarely happen because the flight crew knowingly disregarded a good safety practice. Accidents and incidents happen insidiously. Flight crews fall into traps: some of their own making and some that are systemic.

Let’s look at some examples that could happen when a flight crew employs one recommendation, but disregards another.

Figure 4-C.32

We have identified that nonprecision VOR instrument approaches are especially hazardous when they include shallow approach paths and several altitude step-down points. We recommend that the autoflight system be used, if available, to reduce the workload. While this technique may mitigate the problem with the approach procedure, it can create another trap if the flight crew becomes complacent and does not properly program the computer, monitor the autoflight system, make the proper cockpit callouts, etc.

In another situation, flight crews are encouraged to use the displays that modern cockpits provide to assist them in maintaining situational awareness. However, if they disregard the raw navigational information that is also available, they can fall into a trap if any position inaccuracies creep into the various electronic displays.

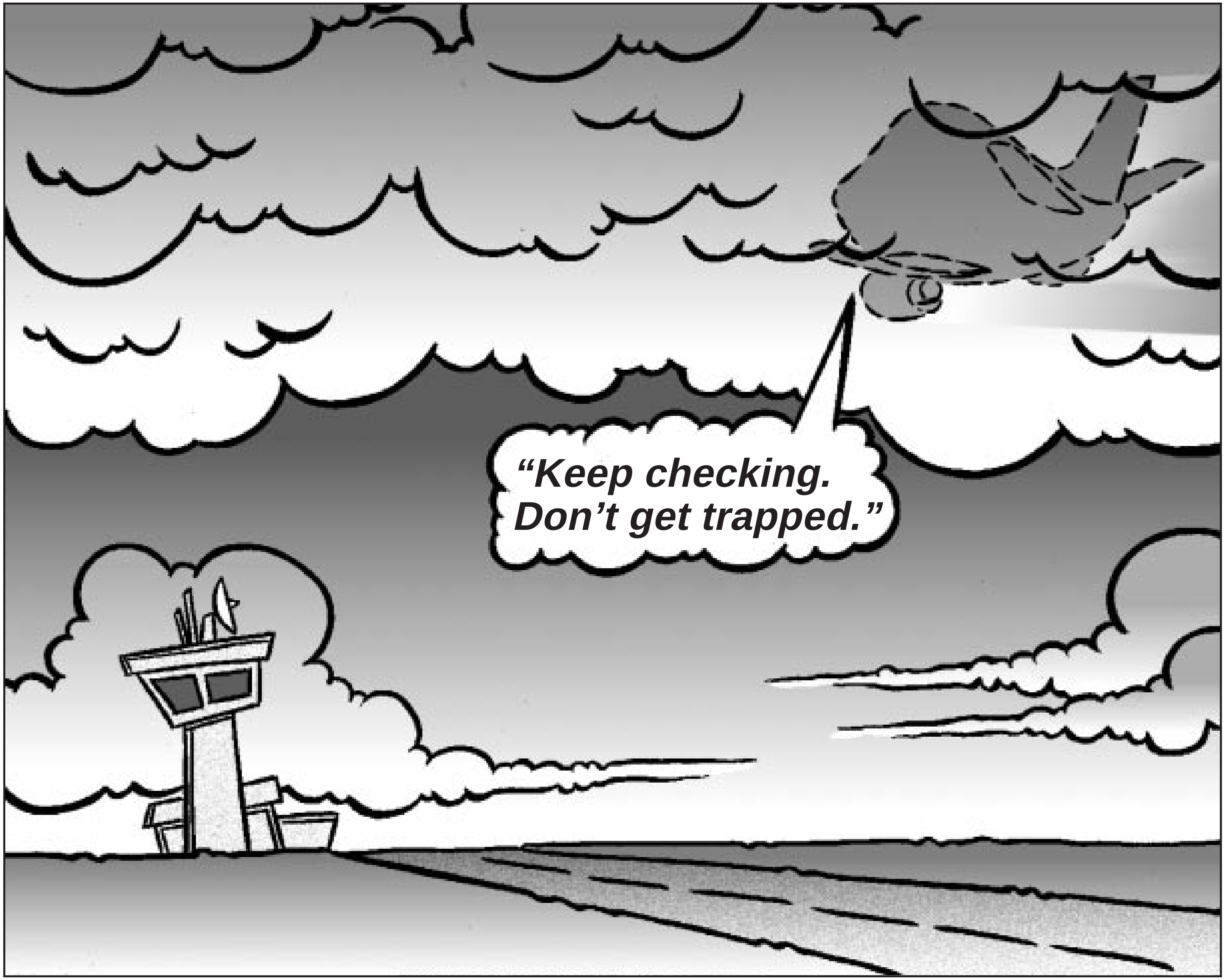


Figure 4-C.33

The importance of takeoff and arrival briefings is stressed as a means to overcome some of the factors associated with the departures and arrivals. However, if the briefings do not stress applicable unique information or become rote or done at the expense of normal outside-the-cockpit vigilance, their value is lost and the flight crew can fall into another trap.


"For this approach,
we've got got some
special considerations."

Figure 4-C.34

It should be evident that there is no single solution to avoiding CFIT accidents and incidents. All the factors are interrelated, with their level of importance changing with the scenario. *Be aware, the traps are there!*

The last link in the chain of events that lead to CFIT accidents is the flight crew. Be ready!

[Optional supporting information]

The CFIT Training and Education Aid, Section 5, CFIT Background Material, provides many more examples of traps.

Are you terrain-proof?

Figure 4-C.35

Escape Maneuvers

Appendix 4-D provides a single-source reference for GPWS warning escape maneuvers. ***Note: The term "maneuver" is associated with the sequence of steps the pilot is required to accomplish in order to avoid impact with the terrain. It is recognized that some airplane manufacturers have established procedural steps that the pilot is required to accomplish for that particular airplane. For simplicity, the term "maneuver" will be used for both situations.*** The generic escape maneuver developed by the CFIT Task Force is included, along with supporting information. This maneuver should be used if your standard operating procedures or airplane manufacturer does not provide other model-specific guidance for reacting to a GPWS warning. Space has also been provided for the insertion of model-specific escape maneuvers and data from airplane manufacturers. Several manufacturers have included their specific escape maneuver and supporting information. Operators who desire additional information, or the escape maneuver for airplanes not included in this appendix, should contact the appropriate manufacturer.

Table of Contents

4-D.1 Generic GPWS Warning Escape Maneuver

In the absence of standard operating procedures or airplane manufacturer guidance, execute the following maneuver in response to a GPWS warning, except in clear daylight visual meteorological conditions when the flight crew can immediately and unequivocally confirm that an impact with the ground, water, or an obstacle will not take place.

- React immediately to a GPWS warning.
- Positively apply maximum thrust and rotate to the appropriate pitch attitude for your airplane.
- Pull up with wings level to ensure maximum airplane performance.
- Always respect stick shaker.

Continue the escape maneuver until climbing to the sector emergency safe altitude can be completed or until visual verification can be made that the airplane will clear the terrain or obstacle, even if the GPWS warning stops.

4-D.1.1 GPWS Warning Escape Maneuver Analysis

Airplane performance data, through computer analysis and simulator studies, were compiled to determine the feasibility of an industrywide, common CFIT escape maneuver. Performance characteristics for specific airplanes were supplied by the various airplane manufacturers.

Preliminary information indicates that performance data for different airplanes are remarkably similar. Using an initial pitch of 20 deg shows a better altitude gain than a 15-deg pitch for the same horizontal distance traveled during the initial pull-up and during low-altitude recoveries. During extended climbs and for recoveries initiated at higher altitudes, the 20-deg pitch will eventually fall below the 15-deg pull-up pitch.

Maximum altitude will be gained in the shortest horizontal distance by using a pull-up directly to stick shaker. However, this technique results in very low airspeeds and varying pitch attitudes, depending on airplane configuration and elevator effectiveness.

Studies show that there is little difference in performance between a pull-up rate of 3 deg/s and 4 deg/s. Because of this, it is recommended that the standard pull-up rate is 3 deg/s. The studies revealed that airplanes in the takeoff configuration had the worst performance characteristics. Data were collected using V2 speed instead of the more nominal V2 + 15 to 25 kt.

Currently, it appears that a 3 deg/s pull-up, similar to a normal takeoff rotation, to a pitch attitude of 20 deg will result in the most altitude gained for horizontal distance used without exposing the flight crew to excessively high pitch attitudes while flying at low airspeeds.